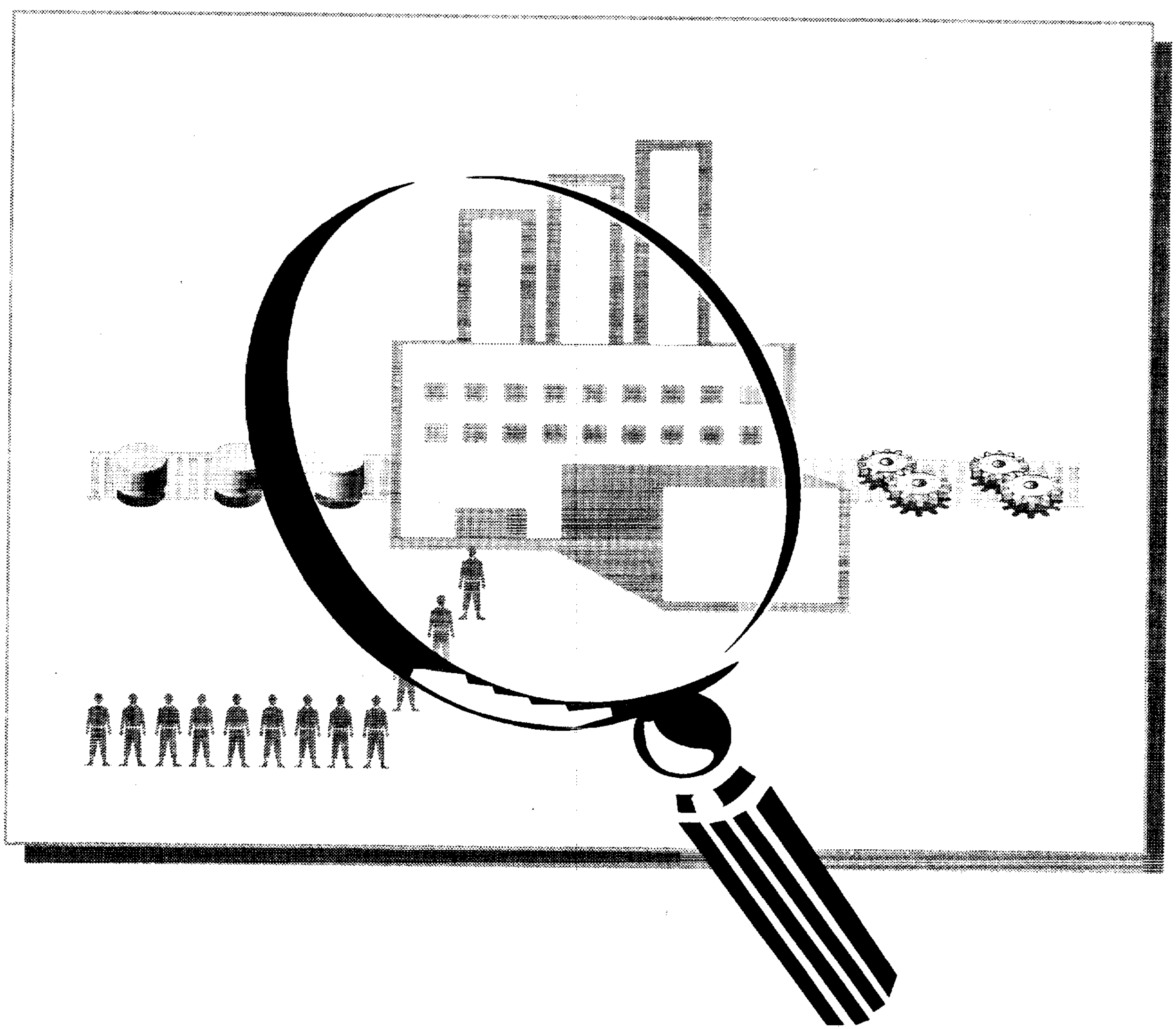
NISTIR 6107

U.S. Department of Commerce
Technology Administration
National Institute of Standards and Technology

Office of Applied Economics
Building and Fire Research Laboratory
Gaithersburg, Maryland 20899

# Estimating Economic Impacts of Government Technology Programs: Manufacturing Studies Using the REMI Model

Mark A. Ehlen and Stephen F. Weber



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December 1997
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# Abstract

Government technology programs such as NIST's Manufacturing Extension Partnership (MEP) work to keep the U.S. economy healthy and its firms globally competitive. Economic tools are needed for gauging the effectiveness of such programs. This report presents one such tool, a model for measuring the microeconomic, industrial, and macroeconomic impacts of government technology programs. This economic impact model is a three-step framework that traces the effects of government program activities on the macro economy. Step 1 calculates the government program's impact on individual firms. Step 2 translates the individual-firm impacts to industry-level impacts. Finally, Step 3 estimates macroeconomic impacts using the industry-level impacts and a macroeconomic simulation and forecasting model called REMI (Regional Economic Modeling, Inc.).

Three economic studies illustrate the impact model. The first two are introductory examples that use a basic version of the model. They analyze two hypothetical benefits provided by a government technology program to individual manufacturing establishments, an increase in their labor productivity and an increase in their exports. The third study is a more detailed analysis based on actual labor productivity increases reported for manufacturers that received assistance from industrial extension centers similar to the MEP centers. This study uses the full version of the economic impact model which has the added capability of capturing non-market impacts that spill over to other firms, and impacts that the government has directly on industries and the larger macro economy. The case study also provides an estimate of the tax revenues that the technology program generates.

The three studies indicate that different types of technology assistance, each with specific benefits to individual firms, often have radically different macroeconomic effects. Productivity-enhancing programs tend to decrease industries' needs for workers except in sectors where productivity-induced cost savings lead to price decreases that significantly increase sales. Export-promoting programs, in the long run, can increase total U.S. output and income as long they are based on a larger trade policy that shifts U.S. production from lower- to higher-productivity sectors (i.e., lower- to higher-wage sectors) and that does not increase significantly the amount of imports used as inputs to U.S. production.

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# Preface

This report was prepared for the Manufacturing Extension Partnership (MEP) at the National Institute of Standards and Technology (NIST). It describes a method for measuring the economic impacts of government assistance programs such as the MEP. The included economic impact model offers analysts a framework by which they can assess a wide variety of government technology programs.

Three studies are provided as illustrations of the impact model. The first two hypothetical analyses, one on increased labor productivity and the other on exports promotion, profile the types of macroeconomic impacts that can be estimated. The third analysis is a case study of actual impacts associated with government industrial extension programs similar to the MEP. It details how manufacturing establishment-level economic impacts are translated into impacts on the macro economy, how the costs of running a government technology program are captured, and how changes in tax revenues can be calculated from computed macroeconomic impacts.

Those unfamiliar with macroeconomic modeling will find the economic impact model useful for formulating the data requirements of macroeconomic analysis. The model is well suited for national, state, and county-level analysis of government technology programs. It can be used to estimate the impacts of technology programs such as the Advanced Technology Program (ATP) and of the NIST laboratory programs that develop technical standards and measurement methods. While the studies in this report focus on the manufacturing industry, the model is equally effective in other sectors such as transportation, construction, and information technology.

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# 1.0 Introduction

## 1.1 Background

The U.S. manufacturing sector is one of the largest, most vital sectors of the domestic economy, producing 18.9% of all U.S. output.[1] It is also very susceptible to technological and economic forces of change. New path-breaking technologies can create thousands of jobs, but at the same time can also wipe out existing industries or at least cause large disruptive shifts of workers from declining to advancing sectors.[2] A sudden rise in financial interest rates can cause an industrial recession as consumers purchase fewer manufactured goods and firms reduce long-term capital investment.

As U.S. business becomes increasingly global, large fluctuations in the exchange rate of the U.S. dollar vis-a-vis other currencies can disrupt merchandise trade between the U.S. and other nations. Individual U.S. manufacturing firms sometimes experience tremendous growth when they expand sales to foreign markets. At the same time they sometimes lose a large share of their domestic business when there is new competition from foreign firms. Lenz (1992) argues

> ... [that] manufactures trade is the primary interface between the U.S. economy and the world economy, that manufacturing is inevitably most exposed to, and bears most of the brunt of, foreign competition, and that improved performance in manufactures trade must be the source of any major improvements in the U.S. trade and current accounts.[3]

The U.S. manufacturing sector is composed mainly of small and medium-sized establishments.[4] Increasing the competitiveness of U.S. manufacturing vis-a-vis the rest of the world is then largely dependent on increasing the competitiveness of these small establishments. Government technology programs such as the Manufacturing Extension Partnership (MEP) at NIST help small domestic manufacturers become more globally competitive.

A number of methods are at the government's disposal for increasing the competitiveness of individual manufacturers. One method is to increase establishments' productive use of labor, capital, and other factors of production. This can be accomplished by educating firms about new production and management techniques that help them increase output using existing resource levels. Increased productivity often leads

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[1] U.S. Bureau of the Census, *Statistical Abstract of the United States 1996*, Table 686. All references in this report to the "manufacturing sector" refer to the set of industries classified by the two-digit Standard Industrial Classification (SIC) codes 20 through 39.

[2] Changes in the manufacturing sector greatly affect other sectors of the economy. For example, for every manufacturing job created, between 1 and 5 additional jobs are created in other sectors, depending on the particular manufacturing industry (based on the authors' calculation of employment multipliers using the REMI model).

[3] Allen J. Lenz, *Narrowing the U.S. Current Account Deficit* (Washington, D.C.: Institute for International Economics, 1992), p. 9.

[4] Of the 387,000 manufacturing establishments in 1994, 83% had fewer than 50 employees and 98% had fewer than 500 employees. Source: US. Bureau of the Census, *County Business Patterns 1994*, p. 8.

to lower prices which increase domestic sales and exports.[5] The government can also help firms promote new products in domestic niche markets, garnering new market share and enabling higher unit prices, or help promote their existing products in international markets. These latter, export-promotion programs can be either direct in nature (such as helping firms with new marketing techniques) or indirect (such as helping firms achieve the ISO 9000 quality standard).[6]

Different government programs, however, have different macroeconomic impacts. For example, government initiatives that increase productivity can have different effects on employment than initiatives that increase exports. Labor productivity increases can reduce the need for workers — less labor is required for the same level of output — unless new sales brought on by productivity-based price declines can offset the job layoffs. Programs that promote U.S. products in foreign markets create new manufacturing jobs, but rapid gains in output can cause excessive price inflation, creating a less favorable exchange rate which makes U.S. goods more expensive to foreign customers. Additionally, this inflation will decrease workers' *real* incomes if it rises faster than *nominal* incomes do.[7]

Economic tools are available which can measure these impacts. Microeconomic tools such as benefit-cost analysis are useful for assessing the impact of a government program on individual establishments. Macroeconomic tools can estimate the impact of one industry's technological change on other industries, on sectoral employment, and on workers' income. But neither alone can compute the macroeconomic impact of individual-establishment changes. What is needed is a method that combines the microeconomic and macroeconomic tools into a unified framework, one that traces impacts from the government program to the individual establishment, to industries, and then to the macro economy. This report presents such a unified economic impact model. A basic and a full version of this model are described in detail in sections 2.1 and 3.1.1.

A major component of the economic impact model is estimating impacts on the macro economy. Macroeconomic forecasting tools exist for estimating these impacts. The studies in this report use the REMI[8] macroeconomic forecasting software, currently being evaluated at NIST. Because the REMI model is a large and complex representation of the U.S. macro economy, a brief description is warranted.

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[5] Empirical research has found U.S. export demand to be highly sensitive to prices; see D.M. Bushe, I.B. Kravis, and R.E. Lipsey. "Prices, Activity, and Machinery Exports: An Analysis Based on New Price Data," *The Review of Economic Studies*, Vol. 68 No. 2, 1986, pp. 248-255.

[6] There are other, more indirect means for making manufacturing firms more globally competitive. The government can attempt to directly depreciate the value of the dollar in world markets (e.g., increasing the number of dollars in the economy by purchasing Treasury bills, notes, and bonds). This can make U.S. manufactured goods less expensive in world markets, increasing exports from the United States.

[7] *Nominal income* is the value of income based on the purchasing power of the dollar in the year the income is earned. *Real income* is the value of income based on the value of the dollar in a reference or baseline year. Nominal income is usually converted to real income using the Consumer Price Index (CPI), a measure of the purchasing power of the dollar in a particular year relative to a baseline year. Since real income equals nominal income divided by the price index, real income increases when the price level (index) decreases.

[8] Formally known as the REMI Economic and Demographic Forecasting & Simulation Model, produced by Regional Economic Models, Inc., 306 Lincoln Avenue, Amherst, MA 01002.

## 1.2 A Primer on the REMI Macroeconomic Model

REMI is a computer program that models the U.S. economy.[9] The program solves a set of structural equations that link macroeconomic variables via causal relationships. The parameters of the equations are estimated econometrically using historical data on the U.S. economy. The parameterized model is then used to forecast future trends and to forecast the impacts of hypothetical changes in the structure of the economy. The economic impact model presented in this report serves as a framework in which REMI can forecast the macroeconomic impact of these hypothetical changes.

REMI's macroeconomic variables include sector output, consumer demand, personal income, employment, wages, and the prices of goods. REMI's variables are used in structural equations which represent economic relationships that are either *behavioral* (such as how consumers respond to changes in the prices of goods), *definitional* (such as the components of national income), or *technical* (such as the percent of the Electrical Components industry's output that is used as material inputs in the Automobile industry). Most of these variables are denominated in dollars.

The structure of the REMI macroeconomic model is easier to understand if its variables are divided into some standard macroeconomic groups or blocks: output; population and labor supply; labor and capital demand; market shares; and wages, prices, and profits. Figure 1 illustrates this grouping. The five blocks in the figure designate collections of macroeconomic variables used for constructing simulations and measuring impacts. The arrows between blocks designate structural equations that represent economic relationships between the blocks of variables.

[9] For a more comprehensive description of the REMI macroeconomic model structure, see George I. Treyz, *Regional Economic Modeling* (Norwell, Massachusetts: Kluwer Academic Publishers), 1993. See also G.I. Treyz, D.S. Rickman, and G. Shao, "The REMI Economic-Demographic Forecasting and Simulation Model," *International Regional Science Review*, Vol. 14 No. 3, 1992, pp. 221-253.

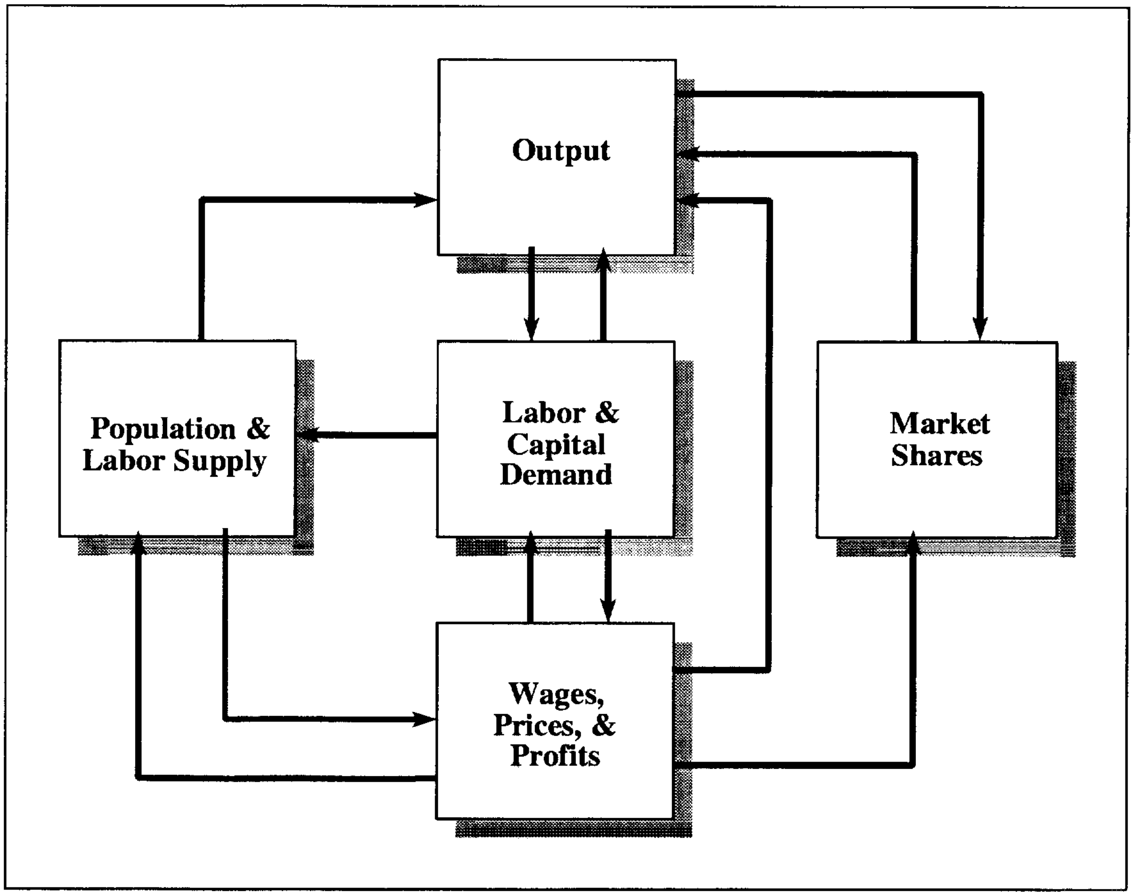


**Figure 1. The REMI Macroeconomic Model**

The Output block contains variables that measure the amount of goods produced by industries. Within the block, these variables are further grouped according to the type of purchase, or demand category of the good: consumption, investment, government spending, exports, and imports.[10] Within each of these demand categories, the variables are further divided into industrial sectors.

The Population & Labor Supply block contains variables that track population levels and migration between regions of the country. The Labor & Capital Demand block includes those variables that impact firms' decisions about how much to produce, how many workers to employ, and the amount of equipment and other capital to acquire.

The Market Shares block contains variables that measure where domestic production is sold (to domestic or to foreign customers) and how consumer demand is satisfied (from domestic production or from imports). The bottom block, Wages, Prices, & Profits, contains price-related variables such as the wage rate, the cost of producing goods, the profitability of firms, and the sales prices of goods.

[10] These demand categories are commonly represented by the equation $Y = C + I + G + (X - M)$, where Y is output, $C$ is consumption, $I$ is investment, $G$ is government spending, $X$ is exports, and $M$ is imports.

Arrows between blocks represent equations stating the economic relationships between variables in different blocks. For example, the arrow pointing from Output down to Labor & Capital Demand represents equations stating that the amount of production in an industry determines the number of workers needed. The arrow pointing from Labor & Capital Demand to Wages, Prices, & Profits represents equations stating that the number of workers and equipment in production determine what wages and the prices of goods will be. Several of the equations represented by the arrow from Wages, Prices & Profits to Market Shares state that the good's price determines how much of U.S. demand for a good is satisfied by U.S. producers.

This report focuses on three macroeconomic variables or measures: value-added output, employment, and real personal disposable income. Value-added output (commonly called Gross Domestic Product or GDP) measures the value added to raw materials by enterprises through workers, plants, equipment, and management. Employment measures the number of workers in the economy and in what sectors they are hired or laid off. Real personal disposable income measures workers' income after taxes, taking into account changes in the prices of the goods they purchase.

These three economic measures are important to any macroeconomic analysis since they are key indicators of how healthy the economy is. Output indicates how productive the current structure of labor and capital is, and for what purposes this production is used (e.g., for consumption or investment). Employment indicates where jobs are being created and phased out, and whether workers are moving to better or worse positions. Real personal disposable income indicates how well workers are paid and how changes in the prices of goods change the quantity of goods they can purchase. Macroeconomic analysis results based on these measures allows the analyst to determine how changes in the level and distribution of output affect the level and structure[11] of employment, and then how changes in employment and output affect the income of workers and their ability to purchase goods.

REMI divides the economy into well-defined sectors so that macroeconomic variables can be tracked in detail. Almost all REMI sectors are defined according to the Standard Industrial Classification (SIC). REMI uses three different SIC-based classifications of the macro economy: a 14-sector, a 53-sector, and a 172-sector classification. REMI can forecast most output measures using all three classifications. The REMI 14-sector classification is shown in Table 1 as an example (Appendix A shows how each sector in the 14-sector classification is composed of one or more sectors from the 53-sector classification). The three studies in this report use the 53-sector classification for constructing the simulations, and use the 14-sector classification for reporting results.

[11] Structure of employment specifies the distribution of workers across industries.

## Table 1. The REMI 14-Sector Classification of the U.S. Macro Economy

| No. | REMI Sector | SIC(s) |
|---|---|---|
| 1 | Durables Manufacturing | 24, 25, 32-39 |
| 2 | Nondurables Manufacturing | 20-23, 26-31 |
| 3 | Mining | 10, 12-14 |
| 4 | Construction | 15-17 |
| 5 | Transportation and Public Utilities | 40-42, 44-49 |
| 6 | Finance, Insurance, and Real Estate | 60-65 |
| 7 | Retail Trade | 52-59 |
| 8 | Wholesale Trade | 50, 51 |
| 9 | Services | 70, 72, 73, 75, 76, 78, 84, 86, 87, 89 |
| 10 | Agriculture, Forestry, and Fishing | 07,08, 09 |
| 11 | State and Local Government | * |
| 12 | Federal Government, Civilian | * |
| 13 | Federal Government, Military | * |
| 14 | Farm | 01, 02 |

Note: An asterisk (*) indicates that there is no SIC for this REMI sector. Sector 10 pertains to agriculture services while Sector 14 pertains to agriculture production.

The majority of the REMI model's parameters are estimated using government data from the 1965-1995 period. For example, state-level Gross Domestic Product (GDP) is taken from the Bureau of Economic Analysis and the *Survey of Current Business.*[12] The data on employment, wages, and personal income come from the Bureau of Economic Analysis and the Bureau of Labor Statistics. The cost of capital is computed from data in the *Quarterly Financial Report for Manufacturing*[13] and from the *Survey of Current Business.* Fuel rate and fuel usage data are retrieved from industry-specific Census reports such as the *Census of Manufacturers*[14] and the *State Energy Price and Expenditure Report.*[15] State and U.S. corporate profits tax rates are based on the *Government Finances (Revenue)*[16] and *Survey of Current Business* publications. Housing price data comes from the *Census of Housing*[17] and the National Association of Realtors.

The REMI model is typically used to forecast the effect on the macro economy of a change in government policy. This policy change could be an increase in the business tax rate or an increase in military spending. A REMI policy analysis is carried out in two steps. In the first step a *baseline forecast* of the U.S. economy is computed over a prescribed time period that follows the last year of historical data. For example, since the REMI model used for this report contains data up to 1995, a forecast can start as early as 1996. In this baseline forecast there is no change in government policy. In the second step a *policy forecast* is generated which models a particular change in government policy. The differences between the baseline and policy forecasts are the estimated macroeconomic impacts of the policy change. REMI uses the same model variables to implement a policy change and to measure the impacts of that change.

Figure 2 gives an example of how macroeconomic impacts are measured. Consider a government policy that would gradually decrease personal income tax rates by some prescribed amount. One macroeconomic impact is an increase in personal disposable income, or the income available to workers after taxes. The lower, solid line in the figure shows the baseline forecast of personal disposable income over the 1996-2001 forecast interval (without the change in tax rates) and the upper dashed line shows the policy forecast for personal disposable income (with the change in tax rates). The difference $\Delta$ between the two lines is the estimated change in personal disposable income that results from a prescribed reduction in personal income tax rates.

[12] U.S. Bureau of the Census, *Survey of Current Business.*

[13] U.S. Bureau of the Census, *Quarterly Financial Report for Manufacturing, Mining, and Trade Corporations.*

[14] U.S. Bureau of the Census, *Census of Manufacturers.*

[15] Department of Energy, Office of Energy Markets and End Use, Energy Information Administration, *State Energy Price and Expenditure Report*, 1992, Washington, D.C.

[16] U.S. Bureau of the Census, *Government Finances (Revenue).*

[17] U.S. Bureau of the Census, *Census of Housing.*

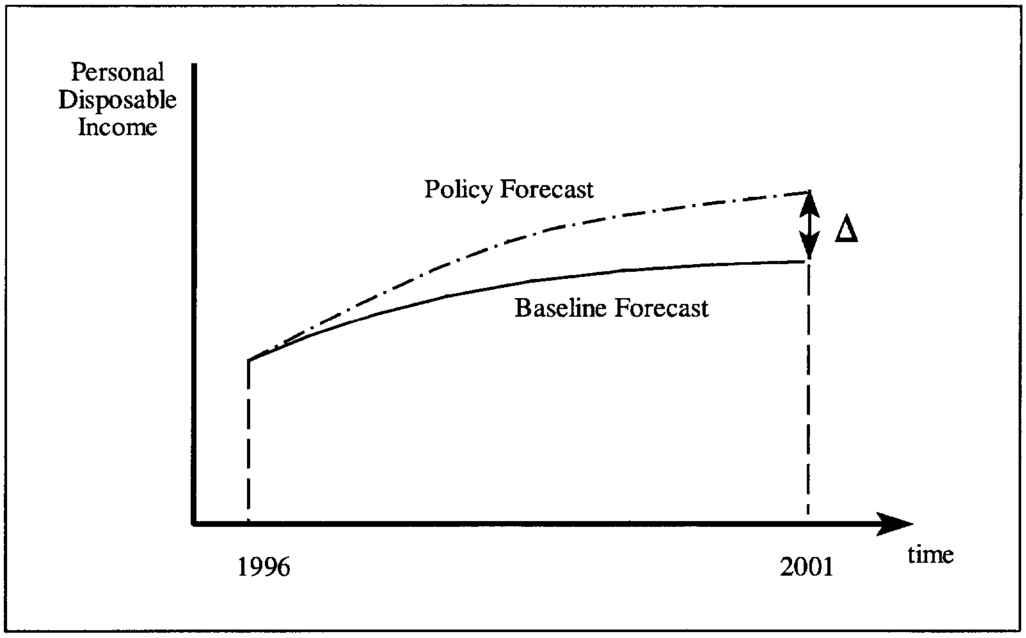


**Figure 2. How to Calculate Impacts using the Baseline and Policy Forecasts**

The set of REMI policy changes should be comprehensive and balanced. To be comprehensive, the set should model all economic activities associated with the policy change. To be balanced, the set should make no net change in the economic resources used to carry out the policy change. For example, in a policy where personal income tax rates decline, decreasing government revenues, the policy change should also include a decrease in government purchases so that the set does not directly change the total number of dollars in the economy.[18] Creating a new government program requires new staff. So that the government policy does not directly change the total number of workers in the economy, the set should include an increase in government employees and an equal decrease in private sector employees. In general, the set of policy variables shift resources from one sector of the macro economy to another.

Figure 3 illustrates an example of a comprehensive and balanced REMI model of the MEP. In this example, the firm-level technological impact is an increase in the labor productivity of manufacturing workers.

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[18] REMI simulations in which the government does not offset higher spending with higher taxes have attracted unwarranted criticism of the REMI model itself. For example, see Edwin J. Mills, "Misuse of Regional Economic Models," *Cato Journal*, Vol. 13, No. 1, Spring/Summer 1993.

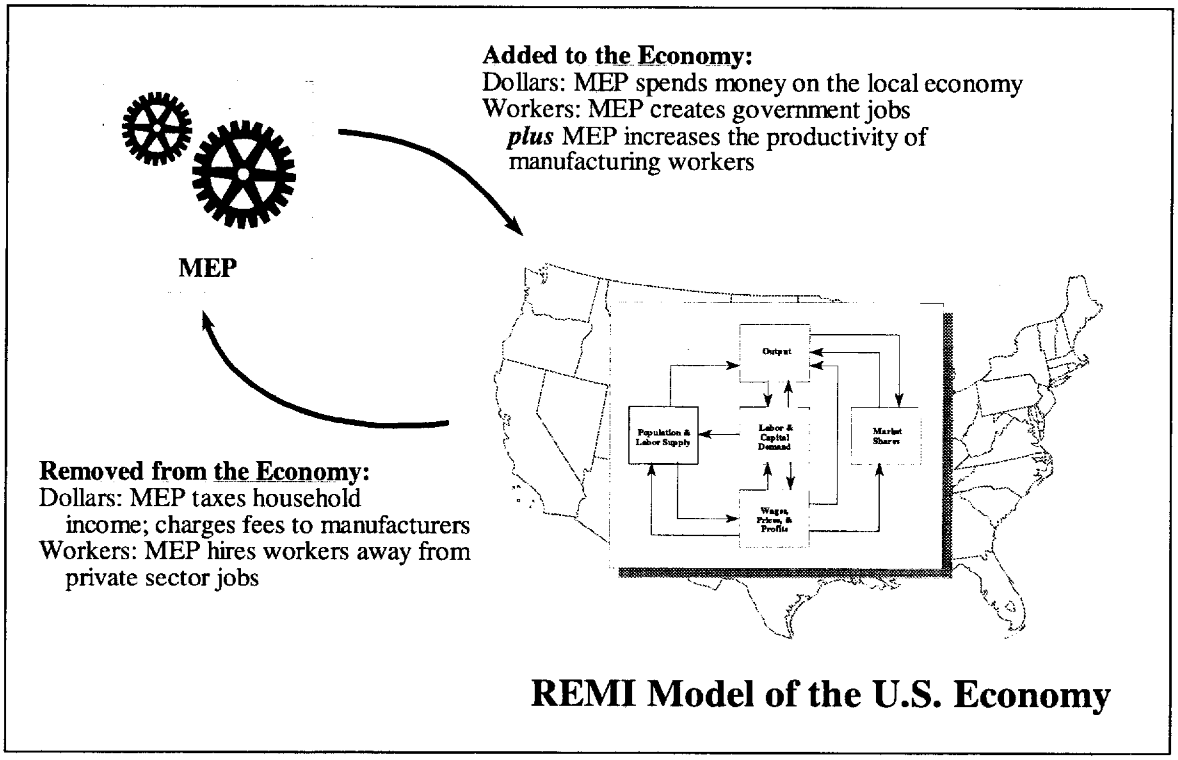


**Figure 3. A REMI Policy-Forecast Model of the MEP**

The lower-right-hand map of the U.S. represents the REMI baseline-forecast model of the U.S. economy. Starting with this model we use policy variables to simulate an MEP program (the upper-left-hand box), creating a policy-forecast model of the economy. To be comprehensive, set of policy variables contain all MEP-related factors that affect the macro economy. The MEP program increases taxes and charges fees for its services. These monies are then used to run the regional offices and pay staff. The MEP hires staff from the private sector and places them in government positions.

To be balanced, the set of policy variables themselves do not change the level of economic resources in the economy (total resources can, however, change as an endogenous response of the economy). In this example, the MEP reallocates two resources: dollars and employees. The model is balanced since the total changes in policy-forecast dollars and employment are zero. The differences between the policy forecast (with the MEP program) and the baseline forecast (without the MEP program) are the macroeconomic impact of the MEP.

## 1.3 Using REMI and the Economic Impact Model to Measure Manufacturing Impacts

The REMI macroeconomic model, in combination with this report's economic impact model, is well suited for simulating a government technology program that assists individual firms. REMI is designed to assess changes in manufacturing competitiveness and includes policy variables such as manufacturing labor productivity, total factor productivity, wages, employment levels, domestic sales and their prices, and exports. The 53-sector REMI model can simulate almost any economic change to the manufacturing sector at the two-digit SIC level. Policy forecasts simulate these changes to the economy and then estimate changes to macroeconomic variables such as personal taxes, the number of federal, state and local employees, and total spending by the government. The economic impact model described in sections 2.1 and 3.1.1 provides the unified framework by which firm-level and industry-level impacts can be developed for use in conducting the macroeconomic analysis executed through the REMI model.

## 1.4 Organization

This report illustrates and applies a method for assessing the economic impacts of government technology programs. Chapter 2 describes the general method for assessing quantitatively the macroeconomic impacts of technology programs. Two example studies using hypothetical government impacts are first provided to give an overview of the model and to describe fundamental macroeconomic concepts.

Chapter 3 describes a detailed case study based on actual establishment-level impacts reported by manufacturers that have received industrial extension services similar to those provided by the MEP. Using U.S. Census data on increases in productivity associated with industrial extension services and data on the administration of the extension program, we estimate the economic and fiscal impacts of industrial extension services on the macro economy. The individual-plant productivity increases are converted to manufacturing-industry increases which are then combined with the extension program activities to form a set of policy-forecast variables for the REMI macroeconomic model. In addition to the macroeconomic measures directly estimated using REMI, the study also estimates changes in federal tax revenues attributable to the productivity increases. Chapter 4 summarizes and concludes.

# 2. Method for Modeling the Impacts of Government Technology Programs

## 2.1 The Basic Model of Economic Impacts

Government technology programs such as the MEP work to directly improve the competitive performance of individual business establishments. The programs are often, in addition, designed to indirectly improve other sectors of the economy. Consider a computer disk drive manufacturing firm that, by government assistance, increases the productivity of its workers, i.e., the firm now has lower labor costs when producing disk drives. This manufacturer *directly* benefits from higher sales if it passes these savings on to its buyers in the form of lower prices. A personal computer manufacturer also benefits *indirectly* since lower disk drive costs lower its own costs of production. Furthermore, purchasers of computers benefit indirectly if the personal computer manufacturer also lowers its prices.[19]

In order to capture the set of direct and indirect impacts that result from government technology programs, we devise a model of how impacts flow causally from the government program to the macro economy. We start in this section with a basic model of economic impacts, one in which impacts flow from the government program to an individual establishment being directly assisted, to the establishment's industry as a whole, and then to all sectors of the economy.[20] Figure 4 illustrates this basic version of the economic impact model. Note that, throughout this report, we define the *macro economy* to include a collection of *industries*, an industry as a collection of *firms*, and a firm as a collection of one or more *establishments* or *plants*. Technological impacts flow from the plants to firms, industries, and then to the larger macro economy.

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[19] A drop in consumer prices increases consumers' *real income* since it allows them to buy a larger basket of goods.

[20] The full version of the model, described in section 3.1.1, includes in Step 1 non-market spillovers and in Step 3 direct impacts on the industries and the macro economy.

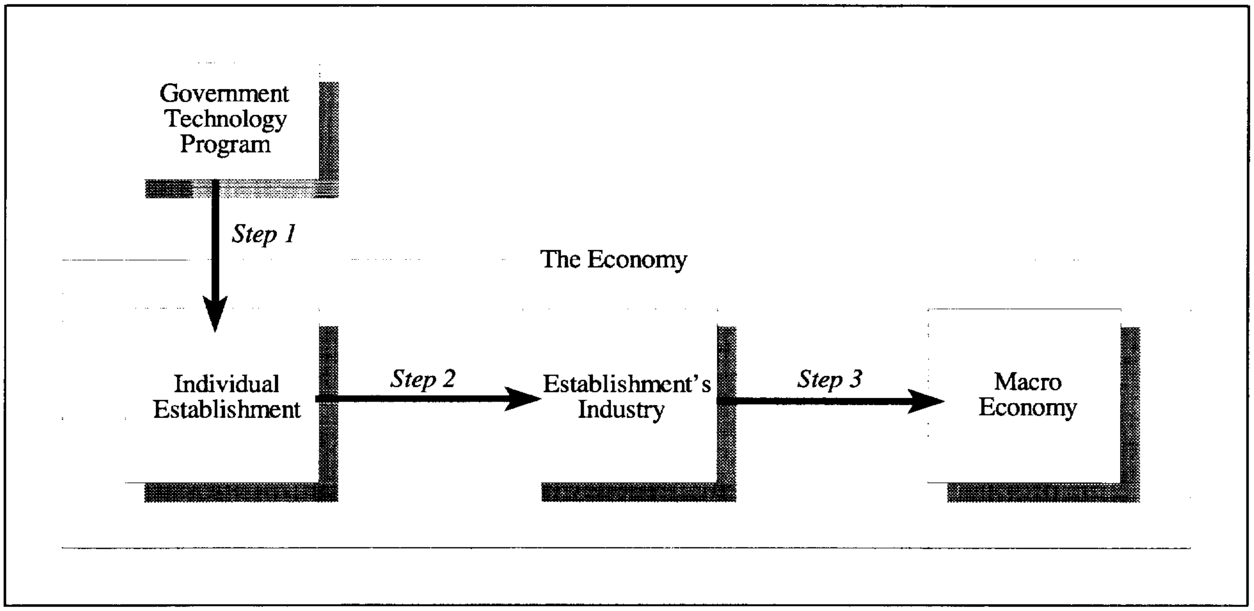


**Figure 4. The Basic Economic Impact Model**

The whole impact is idealized by three causal steps. In Step 1, the Government Technology Program impacts an Individual Establishment (e.g., through an assistance by a regional MEP center to a disk drive manufacturer). As a result, the establishment experiences a change in its performance such as higher worker productivity. In Step 2, the individual establishment impacts the Establishment's Industry by changing, for example, the market price for goods or the level of production. This changes the performance of the entire industry (e.g., other disk drive manufacturers lower their prices to prevent loss of business). In Step 3, the Establishment's Industry impacts the Macro Economy through its interactions with labor markets, material markets, capital markets, and its sales to consumers and other industries (e.g., employment increases in high-wage disk drive and PC industries, increasing income and spending).

Each arrow in Figure 4 represents a step that requires computation using specific economic tools. In Step 1 the analyst estimates the microeconomic impact that the government has on each establishment. For the MEP, one estimate of economic impacts is the U.S. Census Department's survey of establishments that have received MEP services.[21] The analyst can use microeconomic tools to see if the reported impacts are consistent with profit maximizing behavior. In Step 2 the analyst estimates how the entire industry changes, e.g., how firms in the same industry respond to changes in assisted-firms' prices and output. A useful framework for this industry analysis is industrial economics, the study of the economic interaction between firms in the same industry.[22] In Step 3 the analyst estimates the macroeconomic impact of the industry

[21] Individual client establishments are surveyed after their assistance to see what economic impacts the MEP had on the firm. The survey questions include whether the MEP changed the firm's sales, material costs, labor costs, employment, or level of investment.

[22] A useful industrial economics tool is the New Empirical Industrial Organization (NEIO) approach which combines the Structure-Conduct-Performance Paradigm (SCPP) with industry case studies. The SCPP states that the number and structure of firms in an industry determine those firms' conduct (e.g., how they set prices) which in turn determines the industry's

changes. In this report, the Step 3 tool is the REMI macroeconomic model which can forecast the impacts to all sectors of economic changes in individual industries.

Two important considerations affect Step 2's estimates of industry impacts. The first is the impact that an assisted firm has on its own industry. This intra-industry effect is dependent largely on the number and size of firms in the industry. A small firm in an industry composed of many small firms, often called an *unconcentrated* industry, behaves differently than a large firm in an industry composed of a few large firms, often called a *concentrated* industry. Firms in unconcentrated industries tend to act more competitively (e.g., pass labor cost savings on to buyers) than firms in concentrated ones, resulting in more competitive Step 2 industry-level outcomes.

Consider a comparison of the Commercial Printing and Greeting Cards sectors. The Commercial Printing sector (SIC 275) is a relatively unconcentrated industry; it has 35,900 establishments, 94% of which have fewer than 50 employees. All other things being equal,[23] this industry should behave more competitively than the Greeting Cards sector (SIC 277) which has 166 establishments and 50% of its employees work in the four largest.[24] This difference in industry market structure affects industry performance (e.g., the prices at which its products are sold). Small firms in unconcentrated industries that have recently increased their competitiveness (e.g., lowered their prices) are likely to spur similar competitive behavior from the other small firms in their industry. For example, the other firms may lower their prices or improve their product's quality to stem the loss of business to the newly-more-competitive firms. A large firm in a concentrated industry, however, may not obtain any competitive response from the other firms in the industry if the industry's firms have significant market power, e.g., they lose very little market share when an individual firm decreases its price.

The second important Step 2 consideration is the impact that an assisted firm has on unassisted firms. These impacts are often called *spillovers* and can be divided into *market* and *non-market spillovers*. In market spillovers the benefits to other firms flow via economic-market mechanisms such as material cost and wage rate changes. In non-market spillovers the benefits flow to establishments without their having to pay for the benefits in market sense. Firms can pay for these benefits by licensing the technology or hiring a consultant that can educate the firm in its use. An example of a non-market spillover is a firm

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performance (e.g., average price level). The NEIO approach adds industry-specific case studies to this causal paradigm. For a description of the NEIO approach, see T.F. Bresnahan, "Empirical Studies of Industries with Market Power," *Handbook of Industrial Organization* Vol. 2 (New York, NY: North-Holland), R. Schmalensee and R.D. Willig (eds.), 1989, pp. 1011-1057. For a description of the SCPP, see J.S. Bain, *Barriers to New Competition* (Cambridge, MA: Harvard University Press), 1956.

[23] In particular, that the number of plants per firm and the structure of the 'market' are approximately the same for both industries. A better example than this *establishment* example (and one that is directly consistent with the structure-conduct-performance paradigm (SCPP)) would be a comparison of the number of *firms* in each industry. These firm-level data were not available at the time of this report.

[24] U.S. Bureau of the Census, *County Business Patterns 1992*.

observes another firm using a new technology, and then implements it in its own production, free of charge. This type of information spillover is sometimes called a *knowledge spillover.*[25]

An important limitation of the basic version of the model is that it captures market spillovers only. This limitation is not a important in the first two studies since these studies analyze relatively unconcentrated industries where non-market spillovers are considered small. The full model in section 3.1.1, on the other hand, can capture non-market spillovers, an event more likely to occur in concentrated industries.

To illustrate the economic method, sections 2.2 and 2.3 present example studies of two changes to individual establishments' performance, both resulting from government technology programs: a labor productivity increase and an increase in manufactured exports. For each illustration, we describe the government assistance that changes a manufacturing firm's performance (Step 1 in Figure 4). Individual-establishment changes are then used to estimate industry-level changes (Step 2) taking into account the competitive behavior between firms. The REMI macroeconomic model then uses these industry-level impacts to estimate changes in three macroeconomic variables: value-added output, employment, and real personal disposable income (Step 3).

## 2.2 Example Study #1: Economic Impacts of Increased Labor Productivity of Manufacturers

Our first example outlines how to estimate the macroeconomic impacts that result from increases in the labor productivity of manufacturing workers. Labor productivity is defined as the ratio of output to the labor that produced it. One measure of output is *final goods output,* or the value of all goods produced (sales price times quantity sold). Another more common measure of output is *value-added output*, or the value created by workers and equipment net of the cost of the materials used in production. Labor productivity in this latter case is the ratio of value-added output to the labor used in production. Value-added output is preferred to final goods output since it measures more precisely the productive capacity of workers by eliminating variations in the value of materials.

Among other ways, government technology programs such as the MEP can improve manufacturing establishments' productivity by computerizing production, re-training employees to be individually more productive, or reorganizing the production floor of a plant.[26] Increased labor productivity benefits the establishment itself. More output can be produced using the same amount of labor. This lowers the per-unit cost of final goods, allowing the firm to decrease its selling price and be more competitive. The increase also benefits consumers and other industries. Consumers can purchase more of the good or also purchase other goods. Other industries that use the firm's product as a material input benefit from reduced material costs.

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[25] For a discussion of knowledge and other spillovers, see Adam Jaffe, *Economic Analysis of Research Spillovers: Implications for the Advanced Technology Program*, ATP Publication GCR 97-708, 1997.

[26] According the authors' analysis of MEP case studies (August 27, 1996), of a group of 16 establishments citing productivity improvements through MEP assistance, 10 listed their desire to be more efficient as a primary reason for working with the MEP. Fourteen of the 16 establishments specifically took steps to re-organize their current operations.

In this example the government technology program is assumed to increase the labor productivity of every plant in the manufacturing sector by 0.1%. The Step 1 impact (Figure 4) is that each individual establishment increases its productivity by 0.1%. At the same time, individual MEP centers charge client firms for their services. These fees increase firms' production costs, but for this example we assume that the effect of these costs on the firm is small compared to the effect of the productivity increase, and we ignore them.

To measure Step 2 impacts we need to extrapolate each plant's productivity increase to the industry in which it resides. Since each *establishment* increases labor productivity by 0.1%, each *industry* increases its aggregate labor productivity by 0.1%. For all studies in this report we use the 53-sector REMI model which groups manufacturing industries at the two-digit SIC level (e.g., SIC 20); Step 2 impacts are then aggregated at the 2-digit level. For example, if the industry classification of a particular establishment is SIC 3461, then it contributes to industry SIC 34's labor productivity increase. Our Step 2 estimate of impacts is then that manufacturing industries SIC 20 through SIC 39 experience a labor productivity increase of 0.1%.

The REMI model is structured so that all markets behave competitively. This means that a firm whose plant(s) have increased labor productivity will passed these savings on to customers in the form of price reductions. Given that the manufacturing industry is dominated by small production plants and firms, MEP client firms should act competitively, passing the labor productivity increases on to customers in the form of lower prices. For this hypothetical illustration, we assume that each firm changes its prices in this fashion, resulting in lower industry prices.[27]

The REMI model is used to measure how these Step 2 industry changes impact the larger macro economy. Since in this example we are merely interested in outlining the economic impacts of the productivity increase, we do not balance our policy forecast's set of changes to the economy (see section 1.2). A balanced model of the change would include the costs and other activities of the MEP centers that facilitated the productivity increase; we omit these to keep the example study more clear.[28] The following sections summarize key impact modeling assumptions and REMI's estimate of the macroeconomic impacts that result from the 0.1% productivity increase.

### 2.2.1 Impact Model Assumptions

Several assumptions have important effects on the estimated macroeconomic impacts. Some of them have been mentioned previously but it is useful to review the key assumptions in one place.

In Step 1 we assume that the hypothetical 0.1% increase in individual-plant productivity occurs over the 1996-2000 period. Productivity increases in full the first year as opposed to gradually increasing to that level over several years, and it represents a permanent change in the productive capability of workers. A more realistic assumption, used in the Chapter 3 case study, would be to gradually increase industry

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[27] The user would have to modify the REMI simulation to model a market whose firms' behavior is less than perfectly competitive, where decreased production costs do not equally decrease market price.

[28] The full model of economic impacts necessary to model these additional impacts is presented in section 3.1.1.

productivity over the forecast period. Finally, we assume that there are no non-market spillovers to firms that have not been assisted by the MEP.

In Step 2 we assume that the labor productivity increase for each firm translates directly to decreases in the price at which it sells its goods in the marketplace. For example, if the productivity improvement decreases per-unit production costs by one dollar, then the selling price of the final good decreases by one dollar. This represents competitive behavior on the part of (predominantly small) manufacturers.

In Step 3 the macroeconomic impacts are calculated using the REMI model. A baseline forecast is first run over the 1996-2000 interval. A policy forecast simulation is then carried out in which the labor productivity of each two-digit SIC manufacturing sector (SICs 20-39) is increased.

For the policy forecast we assume that, even though there may be changes in net national employment in the short run (one to three years), the Federal Reserve manipulates interest rates so that long-term national unemployment remains at the equilibrium, baseline forecast trend.[29] If job growth is fast enough to accelerate inflation (e.g., due to labor shortages that put pressure on wages), REMI models a Federal Reserve that increases interest rates in order to reduce investment, output, and labor demand, eventually controlling the inflation. Likewise, if unemployment rises too quickly, REMI models a Federal Reserve that decreases interest rates, promoting investment, economic growth, and new jobs.

Finally, this basic version of the impact model ignores the macroeconomic effects of the administration activities of the MEP program — e.g., hiring employees, leasing office space, and financing by increasing taxes. The Chapter 3 case study, however, includes these activities.

### 2.2.2 Estimated Macroeconomic Impacts

The estimated macroeconomic impacts are the differences between the variables in the policy forecast and in the baseline forecast. The REMI program itself forecasts hundreds of economic variables. We concentrate on changes in three macroeconomic variables that describe broad impacts: value-added output, employment, and real personal disposable income.[30]

In particular, we first describe the changes in output, and how the government technology program influences this change. We then describe the changes in employment and explain how the technology program and output change influence these employment changes. We then describe the income change and how the government program, output change, and employment change influence this income change.

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[29] This rate of unemployment is sometimes called the "non-accelerating-inflation rate of unemployment" (NAIRU), the natural unemployment rate, or the equilibrium unemployment rate. For further discussion of this employment policy, see Board of Governors of the Federal Reserve System, "Minutes of the Federal Open Market Committee Meeting Held on July 2-3, 1996," *Federal Reserve Bulletin 82,* 1996, pp. 909-916. For a model of this employment adjustment process, see O.J. Blanchard and D. Quah, "The Dynamic Effects of Aggregate Demand and Supply Disturbances," *American Economic Review,* Vol. 79 No. 4, 1989, pp. 655-673; and W. Nordhaus, "Policy Games: Coordination and Independence in Monetary and Fiscal Policies," *Brookings Papers on Economic Activity* 2, 1994, pp. 139-199.

[30] These three conform to the variables in the top, middle and bottom block in Figure 1: Output; Labor & Capital Demand; and Wages, Prices & Profit. The other two blocks, Population & Labor Supply, and Market Shares, are more important in REMI models of geographic sub-regions of the U.S. economy (e.g., Ohio or the Midwest).

#### 2.2.2.1 Changes in Output

Two measures of value-added output (or GDP) are useful for interpreting the macroeconomic response to the labor productivity increase. The first measure is the change over time of national GDP, or the additional value created by all sectors of the economy. Figure 5 shows REMI's estimate of the net increase in national GDP over the forecast period.

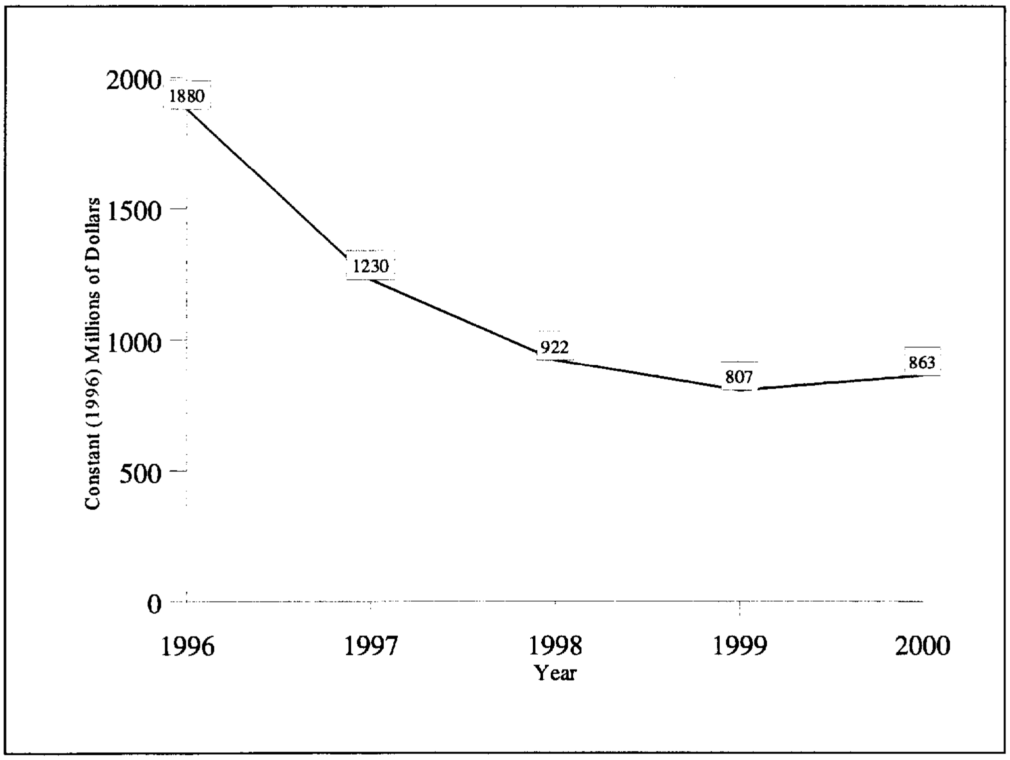


**Figure 5. Change in Total GDP Caused by 0.1% Productivity Increase: 1996-2000**

The 0.1% productivity increase causes national GDP to increase by $1.88 billion in 1996, $1.23 billion in 1997, and $922 million in 1998.[31] The year 2000 increase of $863 billion is a 0.01% increase in GDP. This increase is consistent with the idea that a 0.1% productivity increase for all manufacturing workers, constituting 10% of the U.S. workforce, is expected to increase the productivity capacity of the nation by (0.1% x 10%) = 0.01%.

Durables manufacturing GDP (not shown in the figure) contributes largely to this GDP increase: $1.19 billion in 1996 and $1.22 billion in the year 2000. The durables change is larger than the total change due

[31] All figures in this report are expressed in 1996 constant dollars unless otherwise indicated.

to losses in some sectors. The nondurables contributions for the same years are $257 million and $163 million, respectively.

Figure 4 is a useful guide for explaining how establishment-level productivity increases translate to output increases. The labor productivity improvement at the Individual Establishment level decreases the average sales prices of goods set by their firms and thus by the firms' industries (the Establishment's Industry block). Key elements of the Macro Economy are then impacted by this change in price of (and subsequent change in demand for) manufactured goods: workers' income increases, increasing their consumption of all goods and services. This increases production in most sectors, increasing employment and income, thereby multiplying the impact of the original productivity increase.

The large initial increase in national and manufacturing output declines after three years due to actions taken by the Federal Reserve to control inflation.[32] Initially, national employment increases with output — more labor is required to produce the new output. Limited available labor typically causes wages to increase.[33] These wage increases are passed on to consumers in the form of higher prices of goods. By 1998, the Federal Reserve raises interest rates to control this inflation; this puts downward pressure on output until employment returns to its equilibrium baseline forecast rate. Long-run output has increased permanently, however, owing to the permanent increase in workers' ability to produce value. The net increase in year 2000 output is $863 million.

Our second output measure indicates how the needs for output have changed. These needs can be divided into four "demand" categories: (1) the need of consumers for *consumption*, (2) the need for *investment*, (3) the need for *government spending*, and (4) the need by foreign countries for U.S. goods (*exports*) net of U.S. needs for foreign goods (*imports*). Table 2 shows the year 2000 change in output by these demand categories.

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[32] One could argue that the Federal Reserve would not detect a change in output of this size and thus would not respond with an interest rate increase. First, the Federal Reserve *would* likely detect this change since it follows the manufacturing sectors closely. Second, the Federal Reserve typically increases the interest rate by 25 basis points (0.25%) which is more than the change that REMI is making in these simulations. But REMI forecasts how the Federal Reserve reacts *on average* to output level changes. For example, if the Fed historically increases interest rates by 25 basis points for every $100 billion in "excessive growth" (growth above the baseline trend), then REMI will predict a .25 basis point increase for a $1 billion increase in excessive growth.

[33] The current 1996-1997 economic growth period is unique in that tight labor markets are not causing wages and prices to rise. We use REMI's historically-based wage-pressure response to tight labor markets instead of the current 1996-1997 response since it is too early to determine whether the 1996-1997 employment/inflation trend is a permanent change in the behavior of the macro economy.

## Table 2. Change in GDP Caused by 0.1% Productivity Increase, by Demand Category: Year 2000

| Demand Category | | GDP ($ millions) |
|---|---|---|
| Consumption (C) | | $957 |
| Investment (I) | | $285 |
| Government (G) | | $0 |
| Net Exports (X-M) | | -$379 |
| Exports (X) | | $11 |
| Imports (M) | | $390 |
| | **Total** | **$863** |

Note: All figures are in constant (1996) millions of dollars. Total GDP equals C+I+G+(X-M).

Demand for consumption goods increases by $957 million due to increased income and decreased prices of goods (which increase *real* personal disposable income). Investment increases by $285 million to accommodate the new higher production level. Most of this investment is purchases of new durable equipment to support the new output, followed by residential construction and non-residential construction. Government spending does not change in this basic version of the model.[34]

As indicated by the relative magnitude of the figures, the productivity increase predominantly increases consumption of goods by consumers and firms. The increased productive capacity of workers decreases the prices of goods which in turn allows end users and firms to purchase more goods. Exports increase as U.S. goods become cheaper. Imports increase in response to the higher income.

#### 2.2.2.2 Changes in Employment

Our second measure of impacts is the change in employment. Since the actions of the Federal Reserve keep *long-run* national employment constant (the productivity increase does not increase or decrease the total number of workers; see section 2.2.1), we focus on how employment changes over the short term and how workers move between sectors. We then have two measures which are analogous to the two output measures: the change in employment over time, and the long-run, year 2000 employment change, by demand categories. Table 3 shows how employment in key sectors changes over time. The table groups employees using the REMI 14-sector classification (Table 1).

[34] REMI models a change in government spending as a function of the population's change from its baseline trend. In this simulation the policy forecast population is the same as the baseline forecast population.

**Table 3. Change in Employment Caused by 0.1% Productivity Increase, by 14-Sector Industry: 1996-2000**

| Sector | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|
| Durables | 6365 | 4605 | 4186 | 4167 | 4432 |
| Nondurables | -810 | -1595 | -1976 | -2159 | -2169 |
| Mining | -90 | -211 | -288 | -315 | -309 |
| Contract Construction | 3677 | 2423 | 1564 | 1177 | 1176 |
| Transportation and Public Utilities | -708 | -1640 | -2130 | -2377 | -2449 |
| Finance, Insurance, and Real Estate | 106 | -807 | -1382 | -1677 | -1739 |
| Retail Trade | 8592 | 6689 | 5545 | 5035 | 5154 |
| Wholesale Trade | -2123 | -3412 | -4109 | -4503 | -4697 |
| Services | 6766 | 3559 | 1648 | 730 | 676 |
| Agricuture/Forestry/Fishery Services | 222 | 65 | -27 | -70 | -75 |

Workers move predominantly in response to the changes in output. The Durables sector gains 6,300 jobs in 1996 and this levels off to a 4,400 job gain by the year 2000. Nondurables loses 800 jobs in 1996 and this increases to a 2,100 job loss by the year 2000. Employment in the Services sector initially increases by 6,700 jobs in 1996 and then declines to a 600 job increase in the year 2000. The net change in national employment (not shown in the table) is an increase of 21,900 jobs in 1996 which eventually returns to zero by the year 2000.

By the year 2000, the employment changes caused by the productivity increase have reached steady state values. Table 4 shows how the structure of employment has changed in response to the change in outputs.

**Table 4. Change in Employment Caused by 0.1% Productivity Increase, by Demand Category and 14-Sector Industry: Year 2000**

| Sector | Total | Intermediate Inputs | Consumption | Invest-ment | Govern-ment | Exports |
|---|---|---|---|---|---|---|
| Durables | 4,432 | -501 | -288 | -354 | -5 | 6,075 |
| Nondurables | -2,169 | -1,647 | -696 | -153 | -24 | 351 |
| Mining | -309 | -134 | 1 | -1 | 1 | -177 |
| Contract Construction | 1,176 | 79 | 8 | 37 | 1,149 | -24 |
| Transportation and Public Utilities | -2,449 | -204 | 321 | -18 | 26 | -2,574 |
| Finance, Insurance, and Real Estate | -1,739 | -281 | 474 | -7 | 33 | -1,959 |
| Retail Trade | 5,154 | 4 | 5,348 | 0 | 101 | -299 |
| Wholesale Trade | -4,697 | 716 | 453 | -5 | 62 | -5,923 |
| Services | 676 | 256 | 3,137 | -17 | 56 | -2,756 |
| Agricuture/Forestry/ Fishery Services | -75 | 34 | 72 | 1 | 0 | -181 |

Since the Federal Reserve keeps employment at its long-run baseline trend, the net change in year 2000 employment is zero. The table shows from where and to where workers move. The majority of shifted workers move from exports-based Wholesale Trade, Services, and Transportation/Public Utility production to exports-based Durables manufacturing and to consumption-based Retail Trade and Services output.

Table 4 illustrates the importance of exports in determining whether the 0.1% manufacturing productivity increase has a positive or negative impact on total sectoral employment. Employment for *domestic* production of durables and nondurables *decreases* (the Intermediate Inputs and Consumption columns), responding to the increased productivity of workers. Less labor is needed for the production of consumption goods, intermediate inputs, investments, and government goods. But a large increase in demand for exported durables (predominantly in SIC 35, Industrial Machinery & Equipment), overrides the productivity effect on labor demand, causing a net increase in durables jobs.

These changes illustrate how employment levels are affected by productivity and output changes. The productivity increase affects the prices of goods to domestic and foreign customers, shifting demand and then production levels. This then adjusts labor demand by these sectors. In addition, the productivity increase affects firms' needs for labor. The net effect of the productivity and output changes determines the labor needs for that sector.

#### 2.2.2.3 Changes in Personal Disposable Income

Our final measure is the change in real personal disposable income, or the real value of income received by the average worker. REMI estimates that, by the year 2000, real personal disposable income increases by $984 million (in constant 1996 dollars), or $3.59 per capita.

Two income measures are important for calculating the real increase in worker's income: the change in *nominal* personal disposable income, and the change in the prices of goods purchased with the income. Figure 6 shows how nominal per capita income and real per capita income change over the 1996-2000 period.

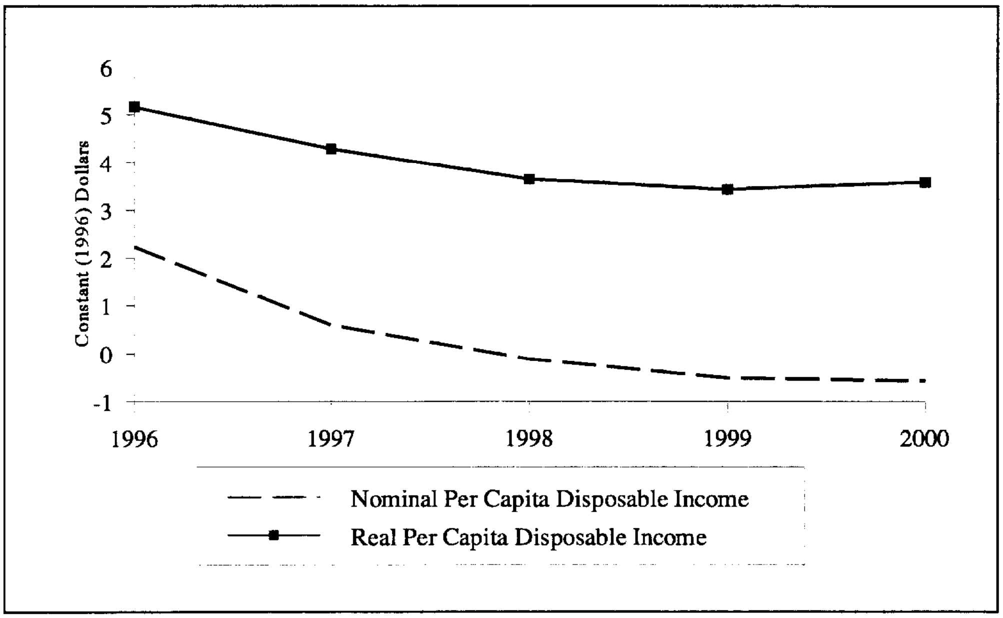


**Figure 6. Changes in Nominal Disposable Income and Real Disposable Income Caused by 0.1% Productivity Increase: 1996-2000**

Nominal income declines steadily over the 1996-2000 period (the bottom dashed line). The productivity gains, on the other hand, have decreased the average price of goods. With prices lower, consumers can now purchase more goods than they could at previous prices. This change in their *real* income (the upper solid line) is positive over the entire forecast interval. Real incomes are now higher.

### 2.2.3 Summary of Example Study #1

We have modeled the response of the economy to an increase in the productivity of individual manufacturing establishments. We used a basic version of the impact model to trace the effects of the government assistance to the individual establishments, to the establishments' two-digit SIC industries, and to the larger macro economy. This model does not include any spillovers that may be received by firms that have not been assisted by the government program (section 2.1) nor does it include any effect that the program has directly on industries or the macro economy (section 1.2).

In this example, establishments, through MEP assistance, increase the amount of goods produced with a given amount of labor. This decreases establishments' per-unit labor requirements. Because the establishments are typically small and their parent firms (also typically small) are in competition with other businesses, these firms pass the cost savings on to their customers. Domestic and foreign customers purchase more goods, recovering some lost employment.

The primary measures of economic impact are changes in output, employment, and real income. Of particular interest are the long run, year 2000 changes. By that year, output has increased by an estimated $863 million, mostly due to increases in durables exports, consumption, and investment. Federal Reserve employment policies bring net national employment back to its equilibrium trend, but workers shift from nondurables manufacturing to durables manufacturing and retail trade. Nominal personal disposable income declines but real income or purchasing power rises due to the decrease in the average price of goods.

## 2.3 Example Study #2: Economic Impacts of Promoting Manufactured Exports

Section 2.2 illustrates how labor productivity gains can indirectly increase manufacturing employment by affecting exports demand. A more direct means of increasing employment through exports might be to directly promote manufactured exports by helping firms find clients in other countries or by helping them comply with foreign countries' protocols of doing business such as the ISO 9000 quality standard. Foreign sales promotion tends to provide significant benefits over domestic sales promotion since foreign sales do not displace the existing domestic sales of U.S. firms.[35]

In this second example we model the macroeconomic impact of a direct increase in individual firms' exports. Following the basic impact model (Figure 4), we model the impacts that the MEP clients have on their own sectors and then on the macro economy. Individual durables manufacturing establishments increase their exports (Figure 4, Step 1) after assistance by the MEP. These increased exports translate into two-digit-SIC industry export increases (Figure 4, Step 2). The change in industry manufacturing exports then affects the entire macro economy (Figure 4, Step 3) in ways similar to those described in the previous productivity example.

For this second example we increases the exports of firms in the Industrial Machinery and Equipment (SIC 35) sector by $1 billion. This focused exports increase allows us to highlight how a particular sector's characteristics affect value-added output, employment, and real personal disposable income in the entire economy.

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[35] However, these new exports may still displace some of the exports of other domestic firms.

## 2.3.1 Impact Model Assumptions

Modeling the impacts of increased exports is difficult since, in addition to the direct effect of exports on the domestic output, they indirectly but significantly affect the macro economy via international trade and currency markets. These international mechanisms complicate calculations in the economic impact model, but this complication can addressed as follows.

The primary purpose of the impact model is to capture all *important* impacts of government technology programs. A large indirect impact of an exports program is an eventual increase in imports due to appreciation of the U.S. dollar (exports increase demand for the dollar, increasing its value vis a vis other currencies, making foreign imports less expensive for U.S. consumers). This indirect imports effect may take 5 to 10 years, longer than is commonly useful for policy analysis. Additionally, REMI does not adequately model this imports response to exports since it is primarily a model of the U.S. *domestic* economy.[36] Other macroeconomic models exist which have more detail on international markets, but they typically have less U.S. domestic detail.

We have two modeling choices: (1) make a relatively precise assessment of the exports impact only, or (2) make a more qualitative assessment of the combined exports/imports impact. Since this chapter's purpose is to illustrate the economic impact model and the qualitative effects of government programs, we choose the latter exports/imports option.

We append to our base exports analysis an equal increase in imports to reflect the international market response to increased U.S. exports. Next, we structure our REMI simulation so that a 5-year forecast gives a qualitative picture of how the economy restructures after 5-10 years. To get this balanced picture in 5 years, we configure the REMI model so that there are no short-run market effects, including excess supply or demand of final goods, intermediate goods, or labor.

In Step 1, individual MEP-assisted firms in Industrial Machinery & Equipment (IM&E) increase their exports over the 1996-2000 period; the aggregate annual sum of these new exports is assumed to be $1 billion. As in the previous example, we keep this study simple by assuming that the fees charged to clients for assistance are small relative to the exports increase, small enough to be ignored.

In Step 2 we estimate the industry-wide changes caused by the increased exports. In accordance with the economic impact model of section 2.1, there is only one industry impact caused by the firms' increases in exports, namely the $1 billion increase in IM&E exports. For clarity we assume that these exports do not crowd out current IM&E exports by other U.S. firms.[37] In Step 3 we model the impact of the $1 billion in exports on the macro economy. There are two Step 3 impacts: the $1 billion exports increase and the international trade response. The trade response is modeled as an equilibriating $1 billion increase in nondurables imports, apportioned according to the 1996 output in each (two-digit SIC) nondurables manufacturing industry.

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[36] REMI does model international trade, but this model is mostly based on the change in the*prices* of U.S. goods relative to the world. In this section we are modeling a change in the level of U.S.*goods* traded with the rest of the world.

[37] The export amount could, however, be adjusted to account for any crowding out of existing exports.

Step 3 now models a combined exports-imports trade policy that promotes exports in Industrial Machinery & Equipment, a high-wage industry, but does not put priority on lower-wage nondurables such as food, apparel, and leather products. IM&E exports are specifically targeted while an increase in nondurables imports is allowed. The trade policy restructures outputs — using the same amount of national labor — to restructure employment toward high-wage durables jobs.

The Step 3 macroeconomic consequences of this new trade policy are again modeled by REMI. Because we are modeling the long-run trade response of an exports increase, we run a long-run REMI simulation of the U.S. economy. Two REMI options configure REMI so that it estimates long-run impacts. In standard REMI simulations, it takes 3-5 years for economic markets to reach equilibrium (where demand equals supply in goods and labor markets) after changes in production levels or price. For this impact simulation we configure REMI so that it models markets that are in long-run equilibrium *every year*.[38] Producer supply exactly equals consumer demand in all goods markets; there is no excess production or excess consumer demand.

Labor markets also clear every year. Workers move rapidly from import-affected nondurables sectors to the IM&E sector while national employment remains at its baseline forecast trend. We use the set of year 2000 economic impacts as a proxy for the long-run impact of the trade policy.

## 2.3.2 Estimated Macroeconomic Impacts

Before listing the specific economic impacts, it is worth noting two primary factors that determine whether export promotion in a particular durables sector (along with the import compensation in all nondurables sectors) will benefit the long-run macro economy: how productive the sector's workers are relative to the rest of the economy and how much of the durables sector's production materials are imported from other countries. Shifting output to high productivity sectors increases overall national productivity and wages. Shifting output to a sector that uses a lot of imported materials can actually *decrease* overall production (and employment) since materials production that was once done in the U.S. is now being done elsewhere. Although the economy may produce more final goods, the fraction of those goods made in the U.S. is lower. These two factors are discussed further in the following section.

### 2.3.2.1 Changes in Output

REMI estimates that the exports-imports trade policy increases value-added output in the year 2000 by \$172 million (in constant 1996 dollars), or by 0.0022%. Durables manufacturing GDP increases sharply (\$747 million) due to the increased exports and the increased output in industries that support IM&E. Nondurables manufacturing declines by \$534 million, mostly due to the increase in the sector's competing imports.

In contrast to value-added output, final goods output (i.e., the sales value of all goods produced in the U.S.) *declines* by \$184 million. The reason for the apparent output contradiction can be explained by the two

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[38] Specifically, national employment is controlled by the REMI Cooperative Federal Reserve Employment Response. This response models a Federal Reserve that observes all changes in national employment *as* they occur and simultaneously changes interest rates to keep employment at its equilibrium level each year. This configuration collapses the model to a Computable General Equilibrium (CGE) model of the U.S. economy.

output definitions. Final goods output is the sales value of final goods produced in the country. Value-added output is the sales value of final goods *minus* the value of intermediate materials used in final-goods production. The difference in the two estimated output measures is the value of intermediate materials provided for U.S. production. Figure 7 illustrates how the trade policy decreases the U.S. materials content.

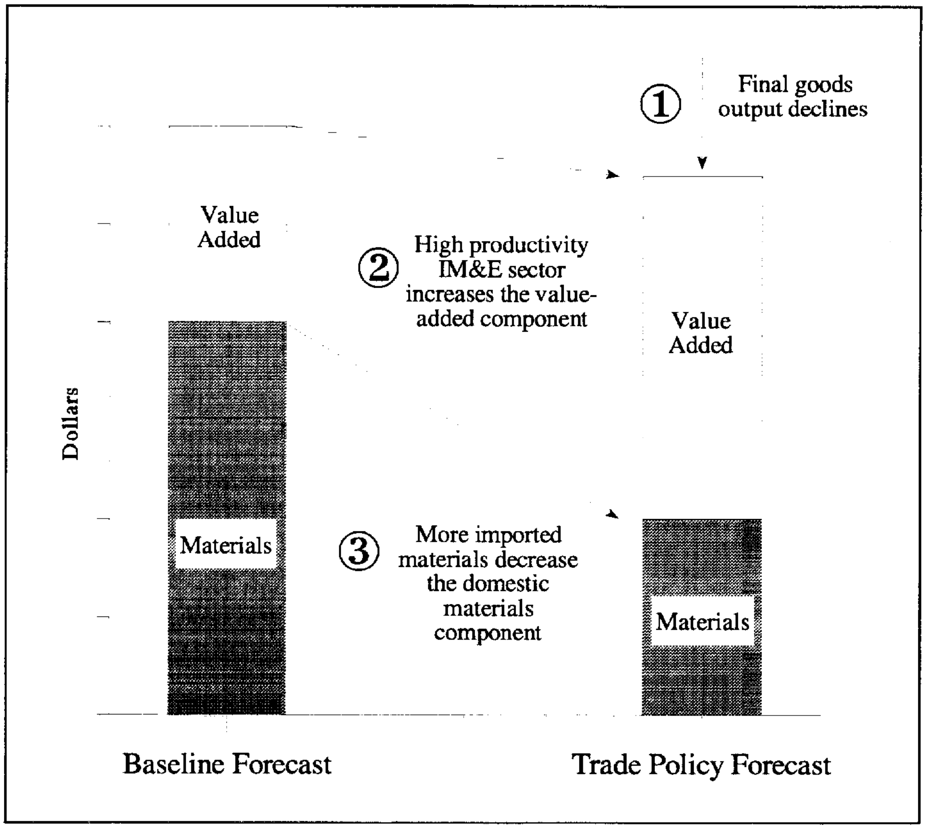


**Figure 7. The Effect of the Trade Policy on Final Goods Output and its Composition of Value Added and Materials**

The Industrial Machinery & Equipment sector uses a higher percentage of imported materials than most U.S. durables sectors.[39] This reduces the need for domestically produced intermediate inputs, decreasing the final-goods value of goods produced in the United States. But of those fewer final goods, *a higher percentage* of their total value is produced by U.S. workers and equipment. Said another way, on average these goods have lower domestic material content but pay more to workers and capital.

Figure 8 illustrates this difference in import content between IM&E and nondurables. In 1996, 29.4% of inputs to Industrial Machinery and Equipment were produced in the U.S. while 46.7% of the inputs to

[39] Specifically, these inputs to IM&E are either directly imported or they themselves have a high import content.

nondurables goods were produced in the United States.[40] Shifting $1 billion of output to durables then reduces the domestic content of inputs to U.S. production.

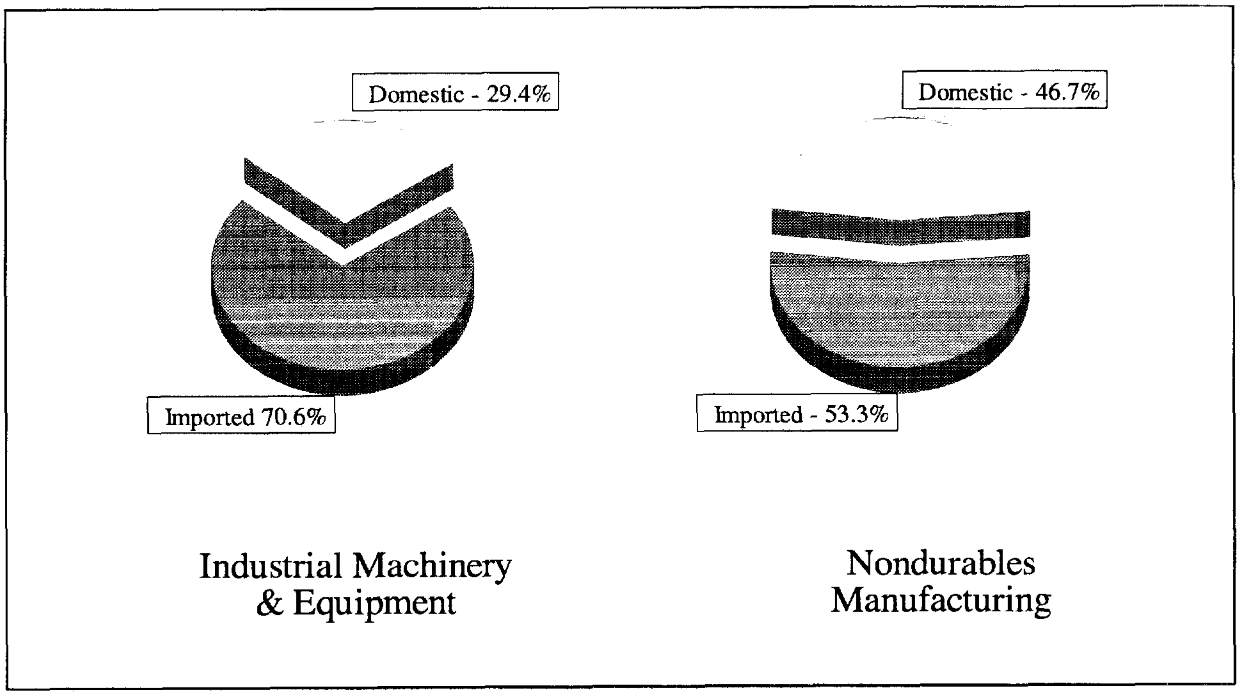


**Figure 8. Percent of Intermediate Inputs Produced in the U.S., Industrial Machining and Equipment and Nondurables Manufacturing Sectors: 1996**

As with the first example study, the impact on output can be measured by how demand for goods has changed. Table 5 shows the change in year 2000 output by demand categories.

[40] Source: authors' calculations using the REMI 53-sector input-output table and 53-sector baseline forecast of the U.S. economy.

## Table 5. Change in GDP Caused by the Trade Policy, by Demand Category: Year 2000

| Demand Category | | GDP ($ millions) |
|---|---|---|
| Consumption | | -$144 |
| Investment | | $5 |
| Government | | 0 |
| Net Exports (X-M) | | $310 |
| Exports (X) | | $641 |
| Imports (M) | | $331 |
| | **Total** | **$171** |

Note: All figures are in constant (1996) millions of dollars.

The majority of the value-added change occurs in products that are exported to other countries ($641 million); this is caused directly by the government exports promotion program. Imports increase by $331 million; they are in large part the materials necessary for the new IM&E production. The changes in exports and imports are different than the $1 billion figures in the trade policy due to the endogenous macroeconomic responses of the entire economy to the trade policy (e.g., consumption, price levels, income changes).

The value added destined for consumption declines by $144 million since consumption is composed of final-goods consumption and consumption by industries that use the goods as material inputs in their production, the latter of which declines sharply. Investments, predominantly in residential construction, increase by $5 million.

To summarize, the trade policy explicitly changes the composition of U.S. final goods output from nondurables to higher-productivity durables manufacturing. The policy increases the amount of labor-created value added that is exported to other nations in exchange for an increase of materials imported for domestic production and consumption.

### 2.3.2.2 Changes in Employment

National employment never changes from the baseline forecast trend under our long-run modeling framework. Labor does, however, shift between sectors, responding to the change in composition of output. Table 6 shows how employment shifts between sectors.

## Table 6. Change in Employment Caused by the Trade Policy, by Demand Category and 14-Sector Industry: Year 2000

| Sector | Total | Intermediate Inputs | Consumption | Invest-ment | Govern-ment | Exports |
|---|---|---|---|---|---|---|
| Durables | 5,742 | 698 | 3 | 1 | -23 | 5,013 |
| Nondurables | -5,591 | -1,236 | 48 | 0 | 0 | -4,407 |
| Mining | -222 | -223 | 1 | 0 | -1 | 0 |
| Contract Construction | 83 | 1 | 1 | -4 | 76 | 0 |
| Transportation and Public Utilities | -311 | -359 | 46 | -1 | -1 | 0 |
| Finance, Insurance, and Real Estate | 79 | -2 | 91 | -1 | 5 | 0 |
| Retail Trade | 385 | -62 | 445 | 0 | -2 | 0 |
| Wholesale Trade | -81 | -12 | 38 | -1 | -8 | 0 |
| Services | -8 | -428 | 414 | -2 | -3 | 0 |
| Agricuture/Forestry/Fishery Services | -54 | -64 | 1 | 0 | 0 | 0 |

As indicated by "Exports" and "Intermediate Inputs" columns, most displaced workers move from nondurables to durables sectors. The choice of export and import sectors in this hypothetical trade policy are such that the new durables jobs almost exactly cancel out the nondurables losses.

The remaining significant job increases occur in the consumption-based Services and Retail Trade sectors, responding to the new income generated by the trade policy.

### 2.3.2.3 Changes in Personal Disposable Income

Nominal personal disposable income increases by $36 million, responding to the new, higher-wage durables jobs. The price of goods decreases by 0.00155% (moving output to higher-productivity IM&E production increases national average productivity, decreasing prices). *Real* disposable income increases by $110 million, or $0.40 per capita.

Because there is no significant increase in the productive capacity of the economy other than switching production to a sector with slightly higher labor productivity, output increases much less than in the prior productivity example. This move to a higher productivity sector also decreases the average price of goods by a smaller amount than in the first example.

### 2.3.3 Summary of Example Study #2

To better tabulate the direct and indirect effects of exports promotion, we model, along with a $1 billion increase in manufactured exports, a $1 billion increase in imports in nondurable sectors, and estimate the long-run macroeconomic impacts to the economy. The REMI model is configured so that it estimates the long-run adjustment, and we use its year 2000 impact estimates as a proxy for the long-run macroeconomic impact.

We increase exports by firms in Industrial Machinery and Equipment (SIC 35) as a hypothetical, targeted MEP program. Imports are also increased in all nondurable manufacturing sectors as a model of the long-run import response. IM&E is chosen because it has higher labor productivity than most durables and nondurables sectors; this should increase wages. But IM&E also has a higher import content than the average for nondurables; this decreases U.S. intermediate-inputs production.

The shift of production from nondurables to IM&E *decreases* the amount of final goods produced but increases the total value added by U.S. workers and capital. A value-added increase is beneficial since it is typically passed on to workers as increased income. This and the reduced price level brought on by the increased labor productivity increase real personal disposable income, further increasing consumption. Employment shifts out of nondurables manufacturing to IM&E and to consumption sectors of the economy.

This completes our two example illustrations of how the basic impact model of section 2.1 can be used to measure macroeconomic impacts of government technology programs. The next section outlines a more comprehensive economic impact model. It then uses the model in a case study of actual labor productivity increases reported for manufacturing clients of eight industrial extension centers that are similar to those affiliated with the MEP.

# 3. Case Study of Government Industrial Extension

In this chapter we analyze the macroeconomic impacts of actual productivity increases reported by clients of industrial extension services similar to those of the MEP.[41] We expand the impact model's capability to capture direct government impacts on the macro economy, allowing us to balance our macroeconomic simulations. The model is also expanded to include impacts that result from non-market spillovers. Spillovers are *not* estimated in this third study but do serve to complete the full impact model (they are important in industries with few firms).

Following the framework of the two previous examples, we first estimate individual firm impacts and then trace them to industries and ultimately the macro economy. Macroeconomic impacts are explained in terms of changes to value-added output, employment, and personal disposable income. We also estimate the impact of the productivity gains on federal tax revenues.

## 3.1 Modeling the Economic Impact of Industrial Extension Services

Recent research by the Census Department indicates that, over the 1987-1992 period, manufacturing establishments that received services from eight industrial extension centers in two states increased their labor productivity significantly more than establishments that did not receive services.[42] The economic impacts of this productivity differential can be estimated using the economic impact model.

In addition to the productivity gains, the administration of the industrial extension services has an impact on the economy. These impacts include higher taxes to pay for the program (or lower government spending elsewhere), state and local spending by regional extension centers, and the hiring of extension employees from the private sector. In general, these impacts should be included in any impact assessment. In particular, though, the REMI model requires that a set of policy-related changes to the macro economy be both comprehensive and balanced.[43] The full version of the economic impact model, described in the following section, allows the user to account for these direct macroeconomic effects.

We model all important activities carried out by the eight industrial extension centers. This insures that all measurable program costs and other activities are accounted for.

### 3.1.1 The Full Model of Economic Impacts

We amend the basic economic impact model in section 2.1 to capture two additional types of impacts, the impact of a government technology program on industries and the macro economy, and impact that firms have on unassisted firms (i.e., spillovers). Figure 9 contains all the elements in Figure 4 but adds Non-

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[41] These regional industrial extension centers eventually became part of the MEP.

[42] R.S. Jarmin, "Evaluating the Impact of Manufacturing Extension on Productivity Growth," Center for Economic Studies (Washington, D.C.: U.S. Bureau of the Census), February 1997. The states remain unnamed to maintain the confidentiality of their regional industrial extension centers.

[43] See section 1.2 for more discussion of this comprehensive balancing process.

Market-Spillover Establishments and Spillover Industries blocks, and new impact lines (shown as dotted lines).

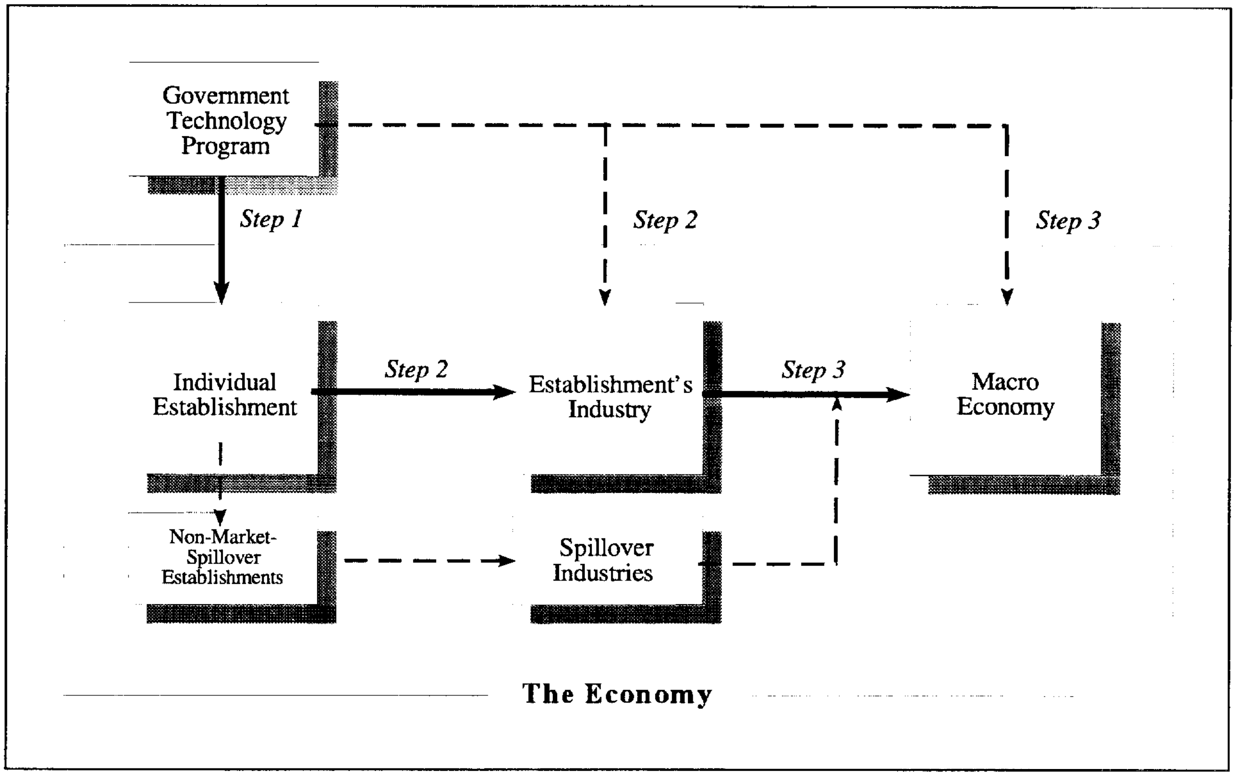


**Figure 9. The Full Economic Impact Model**

The government technology program could impact the entire industry, in particular, in ways that are central to NIST. The development and application of measurement technologies and standards often affect simultaneously all firms in an industry. Government technology programs can also directly affect the macro economy. Actions by the Federal Reserve to set interest rates, or changes in personal income tax rates, affect simultaneously many sectors of the economy.

The economic impact model now has specific non-market spillover channels. Firms other than those directly tied to the government program can benefit from the assistance, resulting in impacts that spread to spillover industries and eventually the macro economy.

### 3.1.2 Step 1: Estimating Plant-Level Productivity Increases

The Census Department's Center for Economic Studies estimates that, over the 1987-1992 period, industrial extension clients in two states increased their labor productivity at a faster rate than establishments that were not clients. The study is based on Longitudinal Research Database (LRD) data of 14,000 manufacturing establishments and data on client services performed between 1987 and 1992.

It estimates the differential labor productivity increase experienced by clients vis-a-vis non-clients, controlling for selection bias. Key results of this research are shown in Table 7.

## Table 7. Estimates of Labor Productivity Increases Associated with Industrial Extension Services

| Case | Total Number of Client Plants (*P*) | Avg. Number of Employees per Plant (*E*) | Client/Non-client Productivity Differential ($\Delta LP$) |
|---|---|---|---|
| | | **Regression Model Specification #1** | |
| **1** | 1418 | 160.1 | **16.0%** |
| **2** | 1105 | 126.6 | **15.4%** |
| | | **Regression Model Specification #2** | |
| **3** | 1418 | 160.1 | **8.2%** |
| **4** | 1105 | 126.6 | **12.6%** |

Four different estimates of the client labor productivity increase were computed, based on two different groups of clients and two different regression model specifications. These estimates are listed as Cases 1 through 4. As an example, in Case 1 there are 1,418 client plants with an average of 160.1 clients per plant. While the labor productivity of the entire Case 1 sample increased by 4.8% over the study period (not shown in table), client establishments' productivity increased 16.0% more than non-clients.

The set of 1,105 client establishments in Cases 2 and 4 are the subset of the 1,418 establishments that have at least 20 but less than 500 employees. Regression specification #2 for Cases 3 and 4 is the same as specification #1 but includes some additional control variables. The estimates of differential labor productivity associated with extension services (the right hand column in Table 7) range from an 8.2% to 16.0%.

The purpose of the case study is to estimate the macroeconomic impacts of these firm-level labor productivity increases. In particular, *by how much does this productivity differential increase value-added output, employment, and real personal disposable income*? The ideal approach would be to estimate the 1987-1992 output, employment, and income that are directly due to the productivity increases. But the currently available REMI model is designed to estimate impacts that occur in 1996 or later.

Our second-best approach is to simulate the labor productivity increase over the 1996-2001 interval and focus on the year 2000 impacts, a time when most of the macroeconomic changes will have occurred. This 1996-2001 simulation of 1987-1992 activities is valid since the REMI model — and in general the economic impact model — estimates impacts using long-run, generally time-independent relationships between components of the macro economy.[44]

Using Figure 9 as a guide, we use the above-average productivity increases for client firms to estimate industry-level productivity changes (Step 2) and then compute macro impacts using the industry changes and the direct impacts of the industrial extension centers on the macro economy (Step 3). The case study does not capture spillovers to other unassisted firms and direct government impacts on industries; these two serve rather to complete the full impact model.

### 3.1.3 Step 2: Estimating Industry-Level Productivity Increases

The Step 2 estimates of industry impacts are largely dependent on the number and size of firms in those industries. Concentrated industries (those with a few large firms) tend to respond less competitively to individual-firm changes than unconcentrated industries (those with many small firms). Figure 10 gives support for the assumption that the manufacturing sector is relatively unconcentrated.[45]

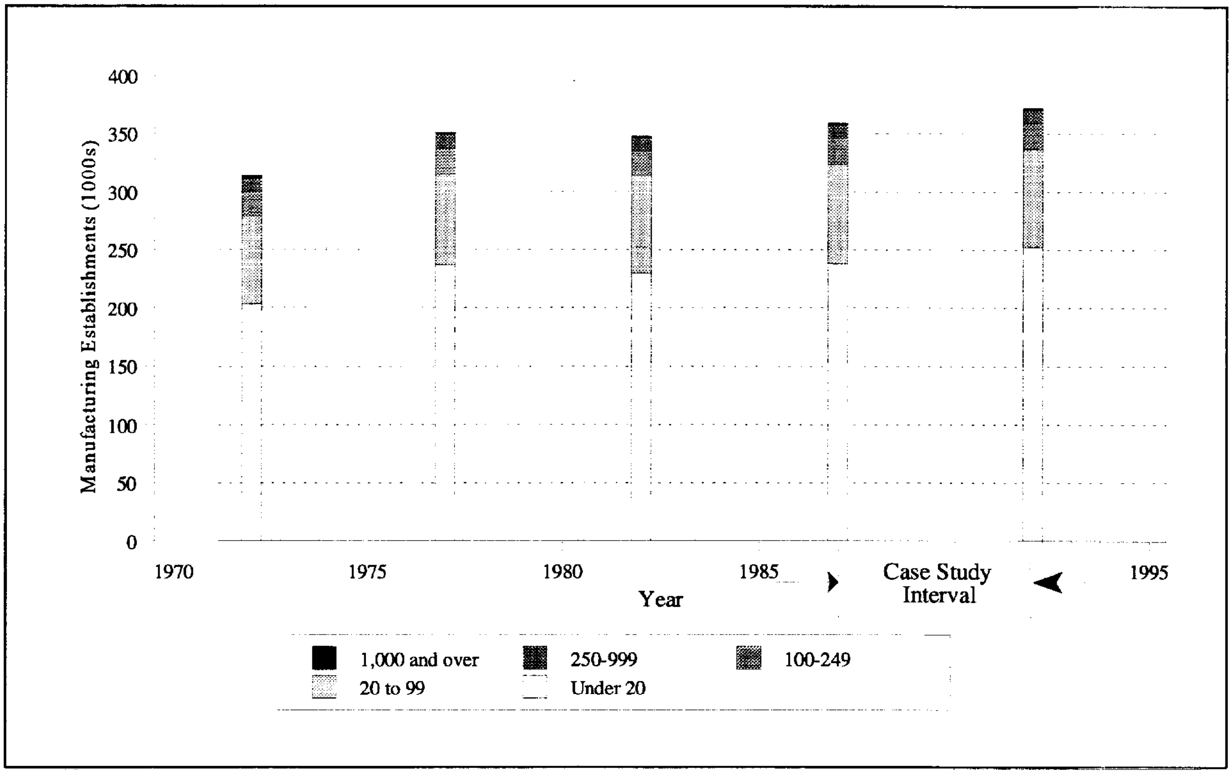


**Figure 10. Number of Manufacturing Establishments, by Employee Size: 1972-1992**

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[44] In addition, the 1987-1992 and 1996-2001 time intervals are similar in that both are periods of economic expansion.

[45] Source of data for Figure 10: U.S. Bureau of the Census, *Statistical Abstract of the United States 1996*, Table No. 1210.

Most establishments have fewer than 20 employees. Using the same logic as discussed in section 2.1, we assume that because of the large number of manufacturing firms, firms whose plants experience productivity gains will generally pass these labor cost savings on to customers in the form of sales price decreases. Thus not only does the average productivity level of each industry increase, but the price of goods in that industry decreases.

Since most manufacturing firms are small, we assume that non-client firms in any sector are not able to obtain the benefits of industrial extension services by simply observing client behavior, i.e., there are no non-market spillovers.

Step 1 firm-level productivity increases are translated to Step 2 industry-level impacts using the Standard Industrial Classification (SIC). Since clients in the LRD data set are in almost all of the two-digit SIC industries, we apportion the labor productivity increase to all two-digit-SIC manufacturing sectors using the two-digit primary SIC of each client. The Table 7 productivity increases are converted to two-digit-SIC increases using Equation 1.

$$\Delta LP_{SIC} = \Delta LP \times \left( \frac{P_{SIC} \times E}{E_{SIC}} \right), \qquad SIC = 20,21,...,39 \tag{1}$$

where

| | |
|---|---|
| $\Delta LP_{SIC}$ | = 1987-1992 U.S. labor productivity increase for particular industry, |
| $\Delta LP$ | = client productivity differential in LRD data set, |
| $P_{SIC}$ | = number of client plants in each SIC, |
| $E$ | = average number of employees per client plant, and |
| $E_{SIC}$ | = number of employees in the SIC in 1992.[46] |

For this analysis we assume that the average number of employees per client plant ($E$) and the productivity increase ($\Delta LP$) are constant across two-digit-SIC manufacturing industries. The values of $P_{SIC}$ are based on the SIC distribution of the client plants in the data set. Table 8 shows the distribution of clients in Cases 1 and 3 of Table 7. This distribution is used to compute industry-level changes in all four Cases.

[46] Source of industry employee figures: U.S. Bureau of the Census, *Statistical Abstract of the U.S. 1996*, Table 1211.

## Table 8. Distribution of Industrial Extension Clients in LRD Data set

| Two-digit SIC | Client Establishments | Non-Clients Establishments | Total Number of Establishments |
|---|---|---|---|
| 20 | 49 | 748 | 797 |
| 21 | 0 | 0 | 0 |
| 22 | 26 | 144 | 170 |
| 23 | 32 | 425 | 457 |
| 24 | 23 | 571 | 594 |
| 25 | 25 | 224 | 249 |
| 26 | 35 | 382 | 417 |
| 27 | 51 | 1441 | 1492 |
| 28 | 48 | 496 | 544 |
| 29 | 0 | 0 | 0 |
| 30 | 94 | 607 | 701 |
| 31 | 0 | 0 | 0 |
| 32 | 49 | 689 | 738 |
| 33 | 81 | 479 | 560 |
| 34 | 277 | 1645 | 1922 |
| 35 | 276 | 2093 | 2369 |
| 36 | 98 | 420 | 518 |
| 37 | 41 | 249 | 290 |
| 38 | 57 | 248 | 305 |
| 39 | 18 | 318 | 336 |
| **Total** | **1280** | **11179** | **12459** |

This distribution of clients is a small subset of all manufacturing establishments in the two states. As well, these states' establishments are a small subset of the total U.S. establishments. It is important, then, that we check the validity of using the larger REMI U.S. model for assessing the impacts of extension of a small number of plants in two states. One method at our disposal to is to compare the employee-size distribution of plants in the client data set, of all plants in the two states, and of all plants in the entire United States. Figure 11 compares these three distributions.[47]

[47] Source of data for distributions of client plants and all plants in the two states: Jarmin (1997). Source of data for distribution of all U.S. plants: U.S. Bureau of the Census, *Statistical Abstract of the United States 1996*, Table No. 1211.

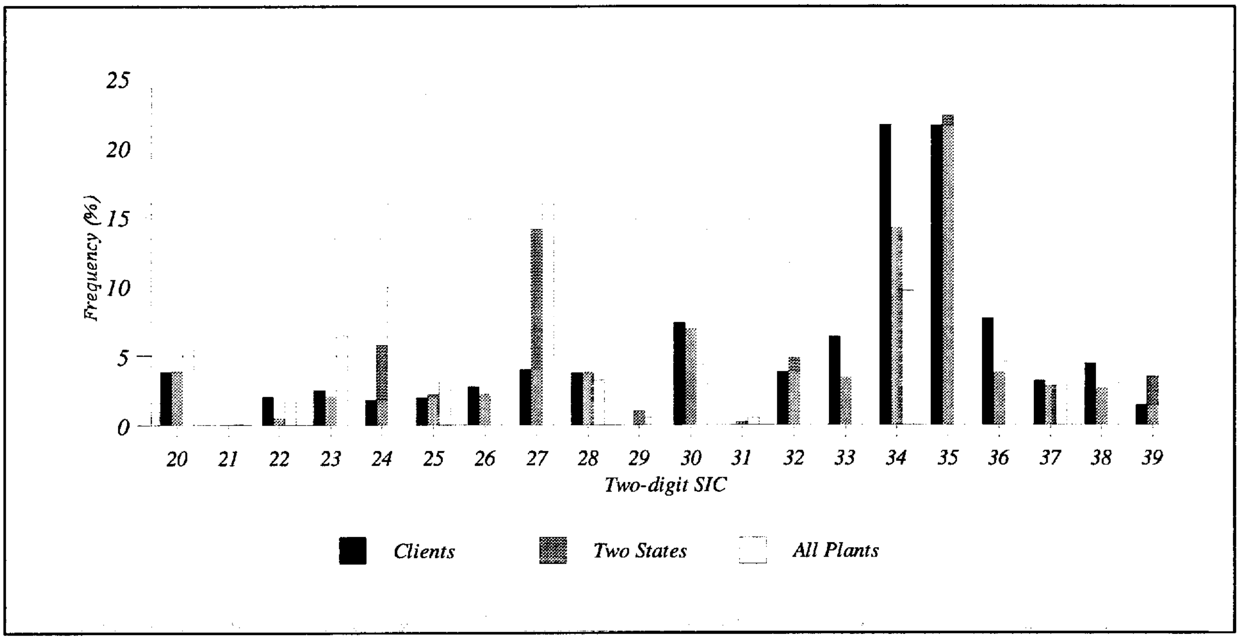


**Figure 11. Percent Distribution of Client Plants, Two States' Plants, and All U.S. Plants, By SIC Industry: 1992**

As an example, the left-most set of black, grey, and white columns shows the share of client plants, two states' plants, and all U.S. plants in SIC 20 (Food and Kindred Products). Three-point-eight percent of clients are in SIC 20, compared to 4.0% of all plants in the two states, and 5.6% of all plants in the nation. For each two-digit SIC (the horizontal axis), the percent of each data set in that SIC is similar except for SICs 23, 24, 27, and 34. This suggests that there is little SIC bias when we use equation 1 to distribute the individual plants' productivity increases to the two-digit SIC industries in the REMI U.S. model.

Figure 12 summarizes the Step 2, industry-level productivity increases computed by Equation 1 and compares them to the 1987-1992 industry-level productivity increases. The black columns represent *100 times* the productivity differential computed by Equation 1 (so that they are measurable in the graph), the white columns are the 1987-1992 productivity increase, and the "mountains" in the background show the level of 1987 output for each industry.[48]

[48] Source of output measures and 1987-1992 productivity increases in Figure 12: National Bureau of Economic Research Manufacturing Productivity Database, Harvard University, Cambridge, Mass.

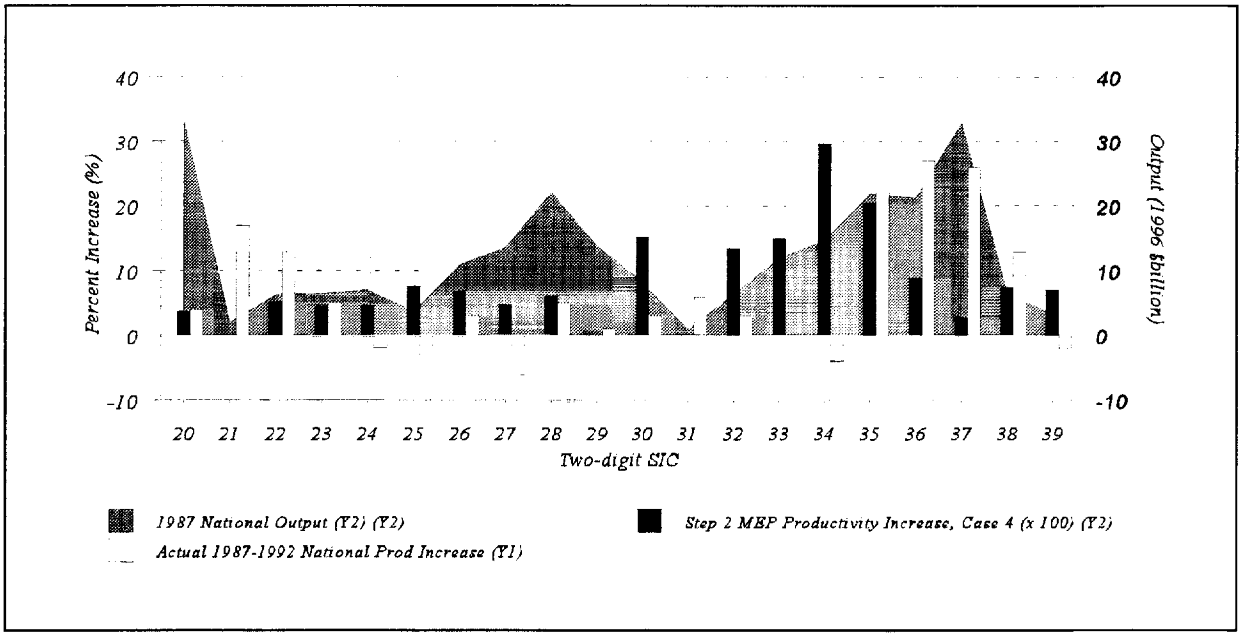


**Figure 12. Industry Output, 1987-1992 Productivity Change, and Extension Services-based Productivity Change, by SIC Industry**

As an example, the left-most tic on the horizontal axis shows how SIC 20 (Food) had $33.0 billion of output in 1987 (the "mountain"), its labor productivity increased by 4.0% over the 1987-1992 period (the white column), and the Step 2, industry-level impact to be simulated by REMI is 0.0374% (the black column which shows 0.0374% × 100 = 3.74%).

Figure 12 illustrates how extension services increased productivity in large sectors experiencing decline and growth. Client establishments in SIC 34, a industry with 1987 output of $14 billion and a 1987-1992 productivity decrease of 4%, increased their productivity 0.3% more than the average SIC 34 plant. Client plants in SIC 35, a $22 billion industry with 27% growth in 1987-1992, increased their productivity an additional 0.2%.

### 3.1.4 Step 3: Estimating Macroeconomic Impacts

The Step 3 impacts are caused by industry changes and impacts that the government program has directly on the macro economy. Unlike the first example study in Chapter 2, this combined set of impacts is a comprehensive and balanced model of an industrial extension program that increases productivity.[49]

The extension services associated with these productivity increases are carried out by regional extension centers in the two states. Paid for with federal and matching state funds, the centers have offices, hire employees, spend money on the local economy in the course of normal business, and charge fees to client

[49] The model is comprehensive to the extent that all *observed* extension service-related benefits to the firm have been modeled. Other benefits may have occurred unnoticed, such as an increase in domestic sales or exports.

establishments. These activities impact the macro economy directly and can be simulated in REMI. Table 9 lists our estimates of the industrial extension activities associated with the labor productivity increases:[50]

### Table 9. Policy Forecast Changes that Reflect Implementation of the Industrial Extension Programs in the Two States

| Change to the Economy | Amount | Step in the Impact Model |
|---|---|---|
| Increased personal taxes | $20M | Step 3 |
| Increased government employment | 100 | Step 3 |
| Increased business spending on the local economy | $10M | Step 3 |
| Fees charged to clients | $2M | Step 1 |

Each change listed in Table 9 is a program-administration activity that impacts either the individual establishment or firm (Step 1) or the macro economy (Step 3). We model these administration activities using approximate figures from compiled data sources.[51] To fund the regional extension centers, federal and state governments increased taxes (or decreased spending in other areas) by $20 million. The centers hired 100 federal, state, and local employees which displaced private sector employees by the same amount. The extension centers spent $10 million each year on the local economy in the course of doing business, and charged a total of $2 million in fees to client establishments.

### 3.1.5 Impact Model Assumptions

The impact model assumptions for Steps 1 and 2 are the same as in the productivity study in section 2.2 Because most manufacturing sectors are not concentrated, we assume that the client labor productivity increases are independent of one another and do not influence the actions of other non-clients. Industry-level labor productivity increases are the sum of plant-level increases.

Three important Step 3 assumptions are made. First, although the actual labor productivity increases occurred over the 1987-1992 period, we simulate them over 1996-2001. Since the year 2000 figures are very similar to the 2001 figures, we describe the results in terms of year 2000 impacts. In all important

[50] For a more complete description of this sub-model, see section 1.2.

[51] M.K. Clarke and E.N. Dobson, *Increasing the Competitiveness of America's Manufacturers: A Review of State Industrial Extension Programs*, National Governors' Association, Washington, D.C., 1991; and Minnesota Department of Trade and Economic Development, Office of Science and Technology, *State Technology Programs in the United States*, St. Paul, Minn., 1988. "Increased Personal Taxes" is the sum of the annual operating budgets of the centers. "Increased government employment" is the sum of all technical, business, and support staff. "Increased business spending" is the total budget (which includes fees from clients) less the cost of support staff (the fully-loaded annual cost of each staff being valued at $100,000). "Fees charged to clients" is the sum of all incomes listed for each center.

qualitative respects, the estimated 1996-2000 macroeconomic impacts are similar to those that occurred over the 1987-1992 period.

Second, we assume that the number of clients that increase their productivity grows linearly over three years and that the increase is a permanent change in the productive capacity of workers. We model then the labor productivity differential in Table 7 as an industry-by-industry increase, 33% of which occurs in the first year (1996), 67% of which occurs in the second year (1997), and 100% of which occurs in the third and all subsequent years. Figure 13 shows what the productivity increase is for Case 1 before apportioning it to two-digit SIC industries.

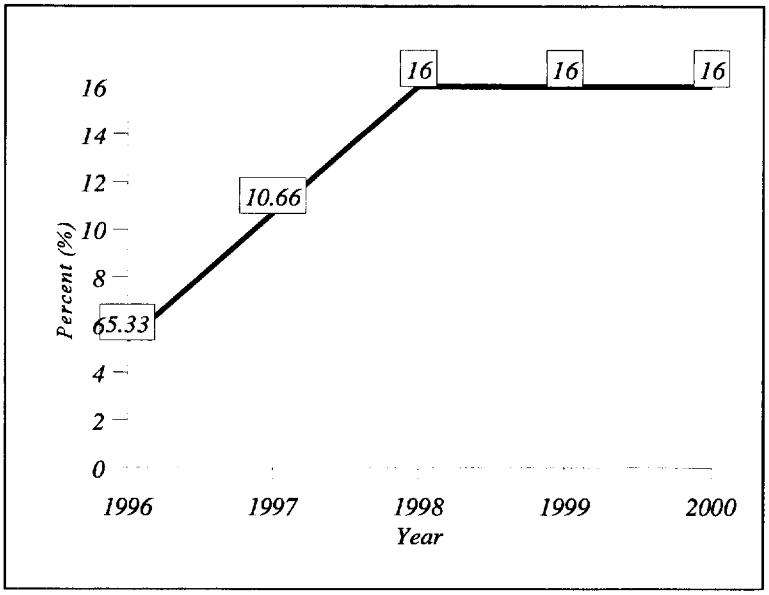


**Figure 13. The Rate of Productivity Increase used in REMI Policy Forecast, Case 1**

Our third and final assumption concerns how net national employment changes over time. We use the same assumption as in the first productivity analysis, where the Federal Reserve manipulates interest rates to keep national employment at a fixed, equilibrium rate. If output and employment grow too fast (possibly causing inflation), the Federal Reserve increases interest rates to reduce inflationary pressures in the economy. Likewise, the Federal Reserve decreases interest rates if unemployment is too high.

## 3.2 Estimated Macroeconomic Impacts

### 3.2.1 Changes in Output, Employment, and Income

Four REMI simulations are run, one for each of the four Cases in Table 7. As in sections 2.2 and 2.3, we describe the estimated macroeconomic impacts in terms of key economic variables: changes in output, changes in employment, and changes in income. Table 10 summarizes these impacts.

## Table 10. Macroeconomic Impacts of Industrial Extension-based Increases in Labor Productivity

| Item | Case 1: 1418 clients 16% Increase | Case 2: 1105 clients 15.4% Increase | Case 3: 1418 clients 8.2% Increase | Case 4: 1105 clients 12.6% Increase |
|---|---|---|---|---|
| | Impacts in the Year 2000 | | | |
| **Output** (constant 1996 millions) | | | | |
| Total Value Added | $2,505 | $1,497 | $1,268 | $1,221 |
| By Demand Category[52] | | | | |
| Consumption (C) | $2,392 | $1,437 | $1,228 | $1,174 |
| Investment (I) | $974 | $598 | $511 | $493 |
| Government (G) | $14 | $14 | $14 | $14 |
| Exports (X) | $103 | $24 | $7 | $7 |
| Imports (M) | $978 | $576 | $492 | $466 |
| **Employment** (# employees) | | | | |
| By Sector | | | | |
| Durables | 19,155 | 11,447 | 9,642 | 9,311 |
| Nondurables | -7,992 | -4,847 | -4,130 | -3,979 |
| Other sectors | -11,163 | -6,600 | -5,512 | -5,332 |
| Net Change | 0 | 0 | 0 | 0 |
| **Income** | | | | |
| Disposable Income ($ M) | $2,392 | $1,437 | $1,228 | $1,174 |
| Price level (%) | -0.054 | -0.033 | -0.0283 | -0.0272 |
| Per Cap. Real Disp. Income | $8.67 | $5.23 | $4.47 | $4.37 |

The four cases from Table 7 are listed in separate columns. For discussion purposes we focus on the results of Case 4.

As described in section 2.2, the macroeconomic impacts in Cases 1 through 4 result primarily from decreased production costs which decrease sales prices, increase sales and increase workers' real income. New sales are strong in export markets, an increasingly important sector for U.S. economic growth. The price reduction also decreases the average price of goods, increasing real personal disposable income.

Value-added output increases by $1.221 billion or 0.013%. Most of this output gain is produced for direct consumption ($1.174 billion), residential investment ($493 million), and imports ($466 million). Industry

[52] Note: Output = C + I + G + (X-M).

output increases are concentrated in durables manufacturing ($1.952 billion; figures not shown in the table). Nondurables output *decreases* by $109 million, Transportation and Public Utilities output *decreases* by $201 million, and Wholesale Trade *decreases* by $512 million.

As indicated in the Employment block in Table 10, most of the labor productivity gains occur in the durables manufacturing sectors: 9,400 new jobs are created in durables manufacturing while 3,900 jobs are lost in nondurables.

**Table 11. Change in Employment Caused by Extension-based Labor Productivity Increases, by 14-Sector Industry: Year 2000**

| Sector | Total | Intermediate Inputs | Consumption | Invest-ment | Govern-ment | Exports |
|---|---|---|---|---|---|---|
| Durables | 9,477 | -1,004 | -225 | -302 | -207 | 11,215 |
| Nondurables | -3,920 | -1,854 | -294 | -98 | -11 | -1,665 |
| Mining | -41 | -207 | 1 | -1 | 9 | -211 |
| Contract Construction | 1,917 | 108 | 1 | -41 | 1,871 | -31 |
| Transportation and Public Utilities | -3,640 | -491 | 432 | -21 | 48 | -3,603 |
| Finance, Insurance, and Real Estate | -2,200 | -437 | 69 | -7 | 52 | -2,493 |
| Retail Trade | 5,589 | -92 | 5,928 | 0 | 178 | -425 |
| Wholesale Trade | -6,620 | 978 | 526 | -6 | 121 | -8,235 |
| Services | -25 | -596 | 3,971 | -18 | 95 | -3,702 |
| Agricuture/Forestry/ Fishery Services | -24 | -62 | 8 | 1 | 0 | -26 |

Aggregate income rises $1.174 billion and, given the decline in the price index of 0.027%, real income increases by $4.37 per capita. Labor productivity increases affect final goods prices (not shown in the table).

### 3.2.2 Changes in Federal Tax Revenues

Another useful impact measure is the change in tax revenues. Increased worker productivity increases aggregate personal income and corporate profits, which in turn increase federal tax payments. We compute the change in tax revenues caused by the productivity increase.

Our tax revenue estimates are based on the change in federal personal income taxes and corporate profit taxes. This is a relatively conservative computation since we do not include state sales taxes or other taxes which can be large at the national level. Personal income tax changes are computed as a fixed fraction of changes in nominal income; corporate profit taxes changes are computed as a fixed fraction of changes in nominal corporate profits, themselves a fixed fraction of changes in GDP (Appendix B details the fiscal calculations). Table 12 summarizes the estimates of fiscal impacts for each of the four cases.

**Table 12. Fiscal Impacts of Industrial Extension-based Increases in Labor Productivity**

| | Impacts in the Year 2000 (constant (1996) millions of dollars) | | | |
|---|---|---|---|---|
| **Item** | **Case 1:** 1418 clients 16% Increase | **Case 2:** 1105 clients 15.4% Increase | **Case 3:** 1418 clients 8.2% Increase | **Case 4:** 1105 clients 12.6% Increase |
| **Total Federal Revenues** | **$391** | **$247** | **$213** | **$207** |
| Personal income taxes | $288 | $186 | $161 | $156 |
| Corporate profit taxes | $103 | $61 | $52 | $51 |

The Case 4 productivity increase generates an additional $156 million in personal income taxes and $51 million in corporate profits tax revenues.

## 3.3 Summary of Case Study

We estimated the economic and fiscal impacts of industrial extension-associated productivity increases that occurred in two states over the 1987-1992 period. Most of the impact modeling assumptions of the first example study (section 2.2) apply to this case study but are refined with some important additions. First, the productivity increase is apportioned asymmetrically across industries using the distribution of clients in the Census data set. Second, the economic impact model is expanded to include the possibility of non-market spillovers and impacts of the government program on industries and the macro economy. Third, the previous section estimates the change in federal tax revenues.

The productivity increase caused output to increase by $1.2 billion. Responding to the new durables output, employment shifted to the durables manufacturing sectors from nondurables and other sectors. Nominal incomes increase and the price of goods decreases, increasing real personal disposable income.

# 4. Summary and Conclusions

## 4.1 Summary

Government technology programs such as the MEP have direct and indirect impacts on firms, industries, and the macro economy. This report presents an impact model designed to assess the economic effects of these technology programs.

The report describes two versions of a three-step economic impact model. The basic version traces economic impacts from individual establishments (Step 1) to the industries in which they reside (Step 2) and then to the larger macro economy (Step 3). The full version adds to this model the non-market impacts that establishments have on other firms (in Step 1), and impacts that the government program has directly on the macro economy (in Steps 2 and 3).

In this report, the REMI macroeconomic model is used to estimate the Step 3 macroeconomic impacts. A summary set of measures — output, employment, and income — are tabulated as examples of the types of impacts that can be estimated.

The basic model is illustrated using two example studies. The first example simulates a 0.1% increase in individual firms' labor productivity. Industry-level productivity increases are computed from the individual firm increases; these are then used as policy variables in a REMI simulation to forecast changes in output, employment, and income. Output increases due to decreases in the cost to produce goods. Although net national employment does not change in the long run, employees do shift from one sector to another.

At least two forces determine the employment change in each sector. Increases in labor productivity decrease labor demand and jobs. At the same time, price reductions made possible by the productivity increase cause sales prices to decline and sales to increase, increasing labor demand. The net change in each sector is primarily a function of these two forces. National income rises due to the rise in output. And since prices decline, real personal disposable income rises. The long run response of the economy to the labor productivity increase is a net improvement in income and consumption.

In the second illustration, exports of manufactured goods are increased by one billion dollars. This export increase is implemented in the Industrial Machinery and Equipment sector (SIC 35) to simulate a focused effort to assist that sector's establishments. Individual-establishment exports are converted to industry-level exports and then a REMI simulation estimates long-run macroeconomic impacts. The $1 billion in SIC 35 exports is matched with a $1 billion increase in nondurables imports to model the long-run response of international trade and currency markets. REMI estimates that final goods output declines but that the value added by workers (and thus income) increases.

This apparent contradiction between the final-goods and value-added output measures is caused by the relative productivity levels of each sector as well as the percent of total output represented by imported material inputs. The Industrial Machinery and Equipment (IM&E) sector has high value added per employee which results in greater productivity gains and income levels. However, the majority of its material inputs are imported. When production shifts from nondurables to IM&E, imports of materials increase. The net effect is that goods prices decline, increasing real income.

The full version of the economic impact model is then illustrated in a case study of eight regional industrial extension services, in two states, that are similar to those currently affiliated with MEP. Recent research by the Census Department indicates that manufacturing establishments in the two states that were industrial extension clients over the 1987-1992 period experienced productivity increases 8.2% to 16.0% greater than the average productivity of non-clients in those states. These individual-plant statistics are converted to industry-wide increases using the SIC distribution of client plants.

The REMI model is then used to estimate the macroeconomic impacts that result from these productivity increases. Included in the REMI simulation are policy variables that model (1) increases in personal income taxes raised to pay for the program, (2) local spending by the regional extension centers, (3) the increase in government employees, (4) the decrease in private sector employees (hired by the centers), and (5) fees charged to individual manufacturing establishments. This REMI policy analysis indicates that the labor productivity gains increase output and income by over one billion dollars.

## 4.2 Conclusions

The economic impact model in this report is a causal framework useful for measuring the impacts of government technology programs. These impacts can include the direct microeconomic, industrial, and macroeconomic impacts that flow via market mechanisms, direct government impacts on individual firms, industries, and the macro economy, and non-market spillover that transfer from one firm to another.

The major conclusion to be drawn from the two example studies in Chapter 2 is that different government technology programs can have very different impacts on the macro economy. In the first, productivity example, employment decreases in most manufacturing sectors except export sectors that have high price elasticities. In the second, exports example, employment increases in the targeted export sectors and sectors that supply materials to the targeted sectors but decreases in most others. Final goods output increases in the productivity example but declines in the exports example due to SIC 35's high percentage of imported material inputs. The analysis suggests that a government technology program that increases productivity *and* exports in all manufacturing sectors would stem the productivity-based loss of jobs in nondurables sectors and stem the exports-based loss of final goods output.[53] The analysis also suggests that the sectoral composition of productivity increases greatly affect the macroeconomic outcomes. For example, the first example study shows how a labor productivity increase in SIC 35, Industrial Machinery and Equipment, actually increases demand for SIC 35 workers due to increased foreign demand for U.S. exports.

At least two important conclusions can be drawn from the case study in Chapter 3. First, the analysis suggests that relatively small, even regional increases in labor productivity can cause large increases in output and income. Additionally, federal tax revenue increases can be significant and even exceed the cost of performing the extension services. Second, productivity increases help keep small manufacturers globally competitive. The average price of goods decreases, increasing the potential for sales abroad as well as reducing the potential for new imports that displace sales by domestic firms.

[53] Research suggests that both are necessary for successful new entrance of small firms in world markets. See S. Clerides, S. Lach, and J. Tybout, "Is Learning-by-Exporting Important?", Board of Governors of the Federal Reserve System, International Trade and Finance Working Paper Series, 1986.

Although the three studies focus on a government program that assists many small manufacturing establishments, the model is sufficiently flexible to analyze a broad spectrum of government technology programs. For example, another research effort is being planned to apply the model to estimate potential macroeconomic impacts of one or more projects funded by the NIST Advanced Technology Program. The macroeconomic impacts of the metrology and standards development programs of the NIST laboratories could also be analyzed using this model.

# Appendix A. The REMI 14-Sector and 53-Sector Classifications of the U.S. Macro Economy

The left-most column of numbers from 1 to 14 is the REMI 14-sector classification while the right-most column of numbers from 1 to 53 is the REMI 53-sector classification.

MANUFACTURING

1 **Durable Goods**

- 1 Lumber and wood products
- 2 Furniture and fixtures
- 3 Stone, clay, and glass products
- 4 Primary metal industries
- 5 Fabricated metal products
- 6 Machinery and computer equipment
- 7 Electronic equipment, except computer equipment
- 8 Motor vehicles and equipment
- 9 Transportation equipment excluding motor vehicles
- 10 Instruments and related products
- 11 Miscellaneous manufacturing industries

2 **Nondurable Goods**

- 12 Food and kindred products
- 13 Tobacco products
- 14 Textile mill products
- 15 Apparel and other textile products
- 16 Paper and allied products
- 17 Printing and publishing
- 18 Chemicals and allied products
- 19 Petroleum and coal products
- 20 Rubber and miscellaneous plastics products
- 21 Leather and leather products

PRIVATE NONMANUFACTURING

3 **Mining**

- 22 Mining

4 **Construction**

- 23 Construction

5 **Transportation and Public Utilities**

- 24 Railroad Transportation
- 25 Trucking and Warehousing
- 26 Local and interurban passenger transit
- 27 Transportation by air
- 28 Other Transportation and transportation services
- 29 Communications

30 Electric, gas, and sanitary services

**6 Finance, Insurance, and Real Estate**

31 Depository and non-depository credit institutions
32 Insurance carriers, agents, brokers, and services
33 Security and commodity brokers and investment services
34 Real Estate

**7 Retail Trade**

35 Eating and drinking places
36 Other retail trade

**8 Wholesale Trade**

37 Wholesale trade

**9 Services**

38 Hotels and other lodging places
39 Personal and miscellaneous repair services
40 Private households
41 Auto repair, services, and parking
42 Business services
43 Amusement and recreation services
44 Motion pictures
45 Health services
46 Legal, engineering and management, and miscellaneous services
47 Educational services
48 Social services, membership organizations, and museums, etc.

**10 Agricultural Services, Forestry, Fisheries, and Other**

49 Agricultural services, forestry, fisheries, and other

**GOVERNMENT**

**11 State and Local**

50 State and local

**12 Federal, Civilian**

51 Federal, civilian

**13 Federal, Military**

52 Federal, military

**FARM**

**14 Farm**

53 Farm

# Appendix B: Federal Tax Revenue Calculations

Equation B1 is used to calculate the change in fiscal revenues listed in section 3.2.2.

$$\Delta F = \left( \frac{T_t^{policy}}{p_t^{policy}} - \frac{T_t^{baseline}}{p_t^{baseline}} \right) \times p_t^{baseline} + (GDP_t^{policy} - GDP_t^{baseline}) \times p_t^{baseline} \times r \qquad \textbf{(B1)}$$

where

| | |
|---|---|
| $\Delta F_t$ | = Change in federal tax revenues (in year *t* dollars), |
| $T_t^{policy}$ | = Personal income taxes in year *t* of the policy forecast (in year *t* dollars), |
| $T_t^{baseline}$ | = Personal income taxes in year *t* of the baseline forecast (in year *t* dollars), |
| $p_t^{policy}$ | = Price level in year *t* of the policy forecast (1987 = 1.00), |
| $p_t^{baseline}$ | = Price level in year *t* of the policy forecast (1987 = 1.00), |
| $GDP_{t,1987}^{policy}$ | = GDP in year *t* of the policy forecast (in 1987 dollars) |
| $GDP_{t,1987}^{baseline}$ | = GDP in year *t* of the baseline forecast (in 1987 dollars), and |
| $r$ | = average corporate tax rate (38%). |

The changes in personal income taxes over the period 1996-2000 are based on the difference between the net federal individual income taxes in the baseline forecast and the simulation forecast. The tax figures used to calculate revenues from personal income taxes are computed by the REMI model.

To compute the change in personal income taxes, the REMI income tax values are converted to 1992 constant dollars using the price deflator *from the particular forecast.* Specifically, the income taxes from the baseline forecast are converted to 1992 dollars using the price deflator from the baseline forecast, and the income taxes from the policy forecast are converted to 1992 dollars using the price deflator from the simulation forecast. The difference of these two 1992 dollar figures is then converted to 1996 dollars using the price deflator of the baseline forecast.

Corporate profits tax changes are computed as 4.1% of REMI's predicted GDP increase, using a historically observed value of "corporate profits as a percent of GDP." Corporate profit tax revenues (as a percent of GDP) were relatively constant over the years 1990-1993, as indicated by government data on before-tax corporate profits, after-tax corporate profits. Corporate taxes as a percent of GDP are computed using the *Statistical Abstract of the United States*;[54] they ranged between 4.1%-4.3% over the years 1990-1993. These same tables are used to verify that the average corporate tax rate, measured as

[54] U.S. Bureau of the Census, *Statistical Abstract of the U.S.* 1995, Tables 700 and 888.

$$\frac{\text{(before-tax profits)} - \text{(after-tax profits)}}{\text{(before-tax profits)}},$$

was relatively constant over the same period. It ranged between 36%-38% over the years 1990-1993.

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